PRAHA 92

XXIII General Assembly
of the European Seismological Commission

ACTIVITY REPORT 1990 - 1992
and
PROCEEDINGS

Volume I

Prague, Czechoslovakia, 7 -12 September 1992

Geophysical Institute, Czechoslovak Academy of Sciences

Pavoni
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ESC

PRAHA 92

XXIII General Assembly
of the European Seismological Commission

International Association of Seismology and Physics
of the Earth's Interior

International Union of Geodesy and Geophysics

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FOREWORD

The XXIII General Assembly of the European Seismological Commission was organized by the Geophysical Institute of the Czechoslovak Academy of Sciences under the auspices of the Government of the Czech Republic and hosted in the premises of the Faculty of Mathematics and Physics of the Charles University in Prague from 7 -12 September 1992.

These two volumes contain a report of the ESC activities during the period 1990-1992 and the Proceedings of the Assembly including the papers presented in the different sessions. These constitute an important sample of the research in seismology being carried out in Europe.

Vladimír Schenk and Dieter Mayer-Rosa
Editors

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PART I.

ACTIVITY REPORT 1990 - 1992

I.U.G.G.

International Association of Seismology and Physics of the Earth's Interior

EUROPEAN SEISMOLOGICAL COMMISSION

Administrative Proceedings
of the XXIII. General Assembly 1992 in Prague

and

Activity Report 1990-1992

edited by
D.Mayer-Rosa
L.Waniek
P.Suhadolc
1993

Preface

The XXIII General Assembly of ESC 1992 was organised by the Geophysical Institute of the Czechoslovak Academy of Sciences and hosted in the premises of the Faculty of Mathematics and Physics of the honourable Charles University in Prague from 7.-12. September 1992. About 350 participants of more than 30 countries attended the various symposia and the about 20 other workshops and sessions. About 270 oral and 70 poster papers have been presented.

The meeting was organised by the Local Organising Committee in Prague, chaired by V.Schenk, very efficiently supported by K.Klíma, P.Kottnauer, T.Lokajíček, J.Plomerová, Z.Schenková, A.Špičák, R.Zimová, further by T.Chlupáč, F.Hampl, J.Hradec, J.Lukášová, E.Petrovský, L.Plešingerová, H.Procházková, V.Strnadová of the Geophysical Institute, and O.Novotný, L.Urban of the Charles University. During the meetings a group of young students of the Charles University also helped very much to make the meeting a success: E.Apostopoulos, P.Bulant, B.Bystrzycká, D.Bystrzycki, J.Chroust, R.Číž, L.Eisner, L.Ivanová, P.Jílek, J.Jindra, P.Nekola, A.Pavlová, Z.Schenková, P.Trefný. The social programme, including a unique concert of chamber music by the Musica Bohemica Praha in the St.George Basilica of the Prague Castle, and several guided tours to the city and other spectacular sites, have been a very welcomed supplement to the scientific sessions.

Congratulations for the excellent work, my dear colleagues in Prague!

This is the last General Assembly which falls into the period I had the honour to serve as Secretary General to ESC. I want to thank all my friends in the ESC who supported me throughout these years in keeping the general goals of our Commission alive. This makes it less difficult to pass the duties to Peter Suhadolc of the University of Trieste, who follows me as Secretary General. I am sure that Peter will continue in the same spirit and with all the enthusiasm necessary in pursuing the objectives of ESC, especially under the new political and economic situation; but he needs also your help.

It was exactly 40 years ago that ESC held its first General Assembly in Stuttgart, organised by W.Hiller. The following persons acted as founding members: M.Båth(S), J.Bonelli (E), P.Caloi (I), C.Charlier (B), G.Grenet (ALG), W.Hiller (G), R.Ingram (IR), I.Lehman (DK), E.Peterschmitt (F), N.Pinar (TR), J.Scholte (NL), E.Wanner (CH), P.Willmore (GB). The decision of having "Titular Members" and Subcommissions dates back to the post-Stuttgart era.

In the following time General Assemblies have been held in Stuttgart 1952, Rome 1954, Vienna 1956, Utrecht 1958, Alicante 1959, Helsinki 1960, Jena 1962, Budapest 1964, Copenhagen 1966, Leningrad 1968, Madrid 1969, Luxembourg 1970, Brasov 1972, Trieste 1974, Cracov 1976, Strasbourg 1978, Budapest 1980, Leeds 1982, Moscow 1984, Kiel 1986, Sofia 1988, Barcelona 1990.

ESC must continue to fight for its idea of European collaboration, including the countries bordering the Mediterranean Sea, but ESC must also be able to renew itself and adapt to changing situations within this area. Its main strength is the activity of the Working Groups, which are set up to co-operate in well-defined projects for a limited period. I found many examples of this spirit in recent years. The projects "TERESA" and "Upgraded European Macroseismic Scale" are only two examples of what I mean with real co-operation.

Two things still worry me on top of all problems in our Commission, and this is how we can attract more young scientist to cooperate actively in the Working Groups, and how ESC can intensify its input to major European projects. Both objectives have not been satisfactorily tackled in the past.

D.Mayer-Rosa
ESC Secretary General 1986-1992

THE XXIII. GENERAL ASSEMBLY OF THE EUROPEAN SEISMOLOGICAL COMMISSION

PRAGUE 7. - 12. SEPTEMBER 1992
Charles University, Troja-Campus

Meeting of the Bureau

Sunday, September 6, 1992, 14:00-16:00

Present: Waniek (Pres.) Mayer-Rosa (Sekr.Gen.), Schenk (LOC-chairman, invited)

1. Changes in the Bureau:
G.Nolet (Vice Pres.) and D.Mayer-Rosa (Secr. Gen.) are resigning

2. Appointments:
Nominating Committee: St.Mueller, R.Adams, N.Kondorskaya
Resolutions Committee: J.Hjelme, P.Burton

3. New Titular Members:
Applications have been received by the Republic of Croatia, Republic of Macedonia, Republic of Slovenia.

4. Next General Assembly:
Invitations by the Department of Geophysics, University of Athens, to host the General Assembly in 1994, and an option by the GeoForschungsZentrum in Potsdam, for 1996, have been received.

5. Proceedings:
The proceedings of the Barcelona meeting 1990 are printed and mailed to all participants in September 1992.

Meeting of the Executive and Local Organising Committees

Sunday, September 6, 1992, 17:00-19:00

Present: Waniek (Pres.), Sobolev (Vice Pres.), Mayer-Rosa (Secr. Gen.), Makropoulos (SC-A), Aichele (SC-B), Eva (SC-D), Berckhemer (SC-E), Schenk (SC-F, LOC), Plomerová (LOC), Adams (IASPEI Rep.)

1. The Prague Meeting:
- The LOC presents the full program of the meeting and describes the different localities for the oral and poster sessions. The poster exhibition will be open from Tuesday to Friday.
- For the publication of the conference papers the following two options are presented: either four pages maximum in the conference proceedings or in a special volume of journals (to be negotiated and announced by the symposia convenors).

- The deadline for resolutions to the Resolution Committee is 24 hours before the Closing Plenary. The resolutions will be posted, after reviewing by the Resolution Committee, from Friday morning.

2. Barcelona Proceedings:
The three volumes of the proceedings of Barcelona 1990 are presented. The Executive Committee thanks A.Roca and the group in Barcelona for the excellent work.

3. EAEE and EMSC Representation
For the period 1992-1994, ESC will be represented in the EAEE by V.Schenk (Chairman SC-F) and in the EMSC by one of the Secretaries.

4. Changes in the Bureau and Subcommissions:
Two new Working groups are announced:
- History of Seismometry (Chairman: G.Ferrari, Bologna) in SC-A
- Macro-seismology (Chairman: M.Stucchi, Milano) in SC-F

5. Varia
- After a short discussion on the role of the Working Groups it is again stressed that, in general, they always should have a specific task and a working plan.
- Some SC-Chairpersons propose more open sessions in the ESC General Assemblies.

Opening Plenary Session

Monday, September 7, 1992, 9:00-10:00

1. General report of the ESC President

Ladies and gentlemen, dear colleagues,

Following the traditions of the ESC Assemblies let me present a short review of ESC activities in the last two years.

The proceedings of the successful XXII. General Assembly in Barcelona were published and distributed just before this meeting. Having the three volumes in our hands, we have to express our gratitude to the editors, A.Roca and D.Mayer-Rosa for their excellent work as well as to all institutions of Catalunya which have made it possible to issue an attractive report.

In general, we can state that the ESC was in the foregoing period a very active scientific body. An ESC business meeting was hold during the IUGG meeting in Vienna last year and the Bureau met on the same occasion. Another meeting of the Bureau was held in Prague in June this year. The main objectives of all these meetings were: 1. to address problems we have to face in the future; 2. to prepare the Prague General Assembly.

It is a well known fact that our Commission gets its life and spirit through the scientific activity in its Subcommissions and Working Groups. Detailed reports by the Chairmen will follow. Some Working Groups launched successful international meetings:

- First workshop on the ESC project "Characteristic Earthquakes and Seismic Hazard", Liblice, 26.-30. November 1990, organised by SC-F and SC-A, convened by V.Schenk.

- Workshop on "Volcanic Tremor and Magma Flow", Saint Roman, March 1991, organised by SAC-A, convened by B.Martinelli.

- Second WG-Meeting on the "Updating of the MSK-81 Intensity Scale", Munich, May 1991, organised by SC-F, convened by G.Grünthal.

- First workshop on "Statistical Models and Methods in Seismology- Applications on the Prevention and Forecasting of Earthquakes", Athens, 27-29. November 1991, organised by SC-A, convened by G.Papadopoulos.

- Third WG-Meeting on the "Updating of the MSK-81 Intensity Scale", Walferdange, 16.-19. March 1992, organised by SC-F, convened by G.Grünthal.

- Workshop on the "Application of Artificial Intelligence Techniques in Seismology", Walferdange, 23.-25. March 1992, organised by SC-F, convened by G.Zonno.

The ESC was an acknowledged partner to important international activities, such as:

- In the organisation of the Conference on Earthquake Prediction: State-of-the-art, held under the auspices of the Council of Europe, Strasbourg, 15.-18. October 1991.

- In 1991 the second phase of the EPOCH programme on Climatology and Natural Hazards supported by the Commission of European Communities started. Our colleagues participated in this programme with earthquake prediction studies, the First Co-ordinating Meeting took place in Athens, 1.-2. June 1992.

- European Seismologists are active in the "Global Seismic Hazard Programme (GSHAP)" which is a principal contribution of the International Lithosphere Project to the UN's International Decade for Natural Disaster Reduction. A technical planning meeting was held in Rome, 1.-3. June 1992 and a special meeting along this line will be organised during this Assembly.

The publishing activity of ESC-seismologists has continued at a high level. The first volume of the Monograph Series on Historical Earthquakes in Europe, edited by R.Gutdeutsch, G.Grünthal and R.Musson has just appeared. This is only one example of many other publications which will be presented during this meeting. It is planned to edit a book on the history of ESC, to which contributions and documents are welcome.

We have to devote more attention to the implementation of resolutions adopted in previous Assemblies of ESC. Therefore, I ask all chairpersons to discuss possible measures to achieve faster implementation. In this connection also the recent structures of the Subcommissions and Working Groups have to be reviewed to adapt to the constantly changed needs.

Our contacts with IASPEI have continued to be solid and close. This statement is supported by the fact that several special meetings of IASPEI commissions are incorporated into the programme of this Assembly. It has to be pointed out that a Joint Project of ESC and IASPEI Commission on Hazard and Prediction was elaborated in Barcelona, started in Vienna last year and will be carried on during this Assembly.

Due to the rapid political changes in Europe the number of ESC member states is increasing. The for a long time nearly constant number of 37 members can grow up to 50 in the future. The ESC Bureau is determined to handle this situation with high priority.

In the past, the venues of biannual meetings of the ESC were alternatively held in different parts of Europe. This has proven to be helpful for the international co-operation and should be continued also in the future.

2. Obituaries:

Vladimir Vladimirovich Beloussov

With great sorrow and regret we took notice that after a short but grave illness Professor Vladimir Vladimirovich Beloussov, Corresponding Member of the USSR Academy of Sciences, died on December 25, 1990, 83 years of age. He was president of the Soviet Geophysical Committee, Professor of the Moscow State University and leading scientist of the Institute of Physics of the Earth. He was fellow of Swedish, Indian and New York Academies and member of the Geological Societies of London, America, France, Belgium, India and Doctor h.c. of Newcastle (GB) and Leipzig Universities. His vision and enthusiasm for international cooperation in geosciences led to the Upper Mantle Project, originally planned for the period 1962-1964, but twice extended, thus ending in 1970 with significant success. For his great work devoted to a better understanding of processes in the Earth's interior, the European Seismological Community owes him great respect and thanks.
(G.A.Sobolev)

Jean-Pierre Rothé

One of the founders of the IASPEI passed away on March 6, 1991. Professor Jean-Pierre Rothé succeeded his father as IASPEI Secretary General in 1942, and remained in office until 1971. From Strasbourg he ran the Bureau Central International de Séismologie (BCIS) whose Bulletins remain one of the great storehouses of seismological information. He was active in all branches of seismology, especially studies of seismicity and hazard, and was one of the first to realise the significance of reservoir-induced seismicity. We shall remember his contributions.
(R.Adams)

Christian Teupser

At the age of 63 Dr. Christian Teupser died on November 9, 1991 in Jena. He studied Physics in Leipzig and Freiberg and in 1954 he joined the Institute for Geodynamics and Earthquake Research in Jena. From his early days he was strongly interested in the exact recording of earthquake ground motions. This lead, under his guidance, to the development and construction of various new seismograph systems. These instruments have been operating in many observatories, especially at the station Moxa. He was one of the founders of the observatory in Moxa. He always was involved in the improvement of instruments, thereby contributing to the high reputation of the Observatory. He combined science of seismology and the art of constructing good seismographs in one person. We will always remember him.
(K.D.Klinge)

Daniele Postpischl

On June 6, 1992, Daniele Postpischl died at the age of 48. Assistant professor at the University of Bologna, Faculty of Engineering, he has been active for about 20 years in seismology and geophysics, serving as chairman of working groups in the frame of the National Geodynamics Project and the National Group for Protection against Earthquakes in Italy. He has been a convenor of symposia on historical earthquakes of ESC and EGS, and an active member of the WG "Macroseismic Scales" up to the last meeting in March 1992, short before his death. Most European seismologists know him through the "Catalogue of Italian Earthquakes" and the "Atlas of Isoseismal Maps" which he edited in 1985. He was one of the leaders of the macroseismic survey after the 1980 earthquake in southern Italy. Daniele´s main characteristic was his free spirit; he was one who always tried and went his way, no matter what it cost to him. It was pleasant to spend time with him, in any circumstance. And that is probably the main point:
we miss a friend.
(M.Stucchi)

3. Call of Titular Members

Country	Titular Member (Changes for 1992-1994)	confirmed	present in Prague	proxy in Prague
Albania	E.Sulstarova	1.9.92	√	B.Muco
Algeria	M.Benhallou	16.6.92		
Austria	J.Drimmel (W.Lenhardt)	12.6.92	√	W.Lenhardt
Belgium	T.Camelbeeck		√	
Bulgaria	L.Christoskov	31.8.92	√	
Czechoslovakia	L.Waniek	18.4.92	√	
Denmark	J.Hjelme	4.9.92	√	
Egypt	M.Ibrahim (M.Dessokey)	1.9.92	√	M.Dessokey
Finland	H.Korhonen (U.Luosto)	3.6.92	√	U.Luosto
France	M.Cara		√	
Germany	K.P.Bonjer (F.Scherbaum)	21.8.92	√	
Greece	J.Drakopoulos		√	K.Makropoulos
Hungary	T.Zsiros			
Iceland	R.Stefansson	26.8.92	√	
Ireland	A.W.B.Jacob	25.8.92	√	D.Mayer-Rosa
Israel	A.Shapira (A.Hofstetter)	30.6.92	√	A.Hofstetter
Italy	C.Morelli (C.Eva)	13.8.92	√	C.Eva
Jordan	Z.El-Isa	25.8.92		
Lebanon	J.Plassard			
Luxembourg	J.Flick	26.5.92	√	
Malta (obs.)	P.Galea			
Morocco	D.Ben Sari	25.6.92		
Monaco	N.Bethoux			
Netherlands	T.de Crook	11.6.92	√	
Norway	S.Mykkelveit	25.8.92	√	D.Mayer-Rosa
Poland	R.Teisseyre			
Portugal	L.Mendes Victor	15.6.92	√	
Romania	L.Constantinescu (D.Enescu)	1.9.92	√	D.Enescu
Russia	S.Arefiev	1.9.92	√	
Spain	J.Mezcua	3.9.92	√	G.Payo
Sweden	O.Kulhanek	3.6.92	√	
Switzerland	D.Mayer-Rosa		√	
Tunisia	M.Allouche			
Turkey	A.Neclioglu			
United Kingdom	R.Pearce		√	

4. Activity reports of the Subcommissions

A: Seismicity of the European Region: by K.Makropoulos
B: Data Acquisition, Theory and Interpretation: by H.Aichele
C: Physics of Earthquake Sources: by A.Udias
D: Deep Seismic Sounding: by C.Eva
E: Earthquake Prediction Research: by H.Berckhemer
F: Engineering Seismology: by V.Schenk

The full reports, as received, are found under the chapter "Subcommissions"

5. Announcements

At this point announcements are made concerning the organisation and facilities of the meeting.

6. Opening of the General Assembly

The President declares the XXIII General Assembly 1992 open.

Opening Ceremony

Monday, September 7, 1992, 16:30, Carolinum, Charles University

Prof. A.Baudyš, Deputy Prime Minister, Government of the ČSFR

Mister Chairman, Ladies and Gentlemen,

It is an honour and a pleasure to be able to welcome you, the participants of the twenty-third General Assembly of the European Seismological Commission, in the Great Hall of the historic Carolinum. As representative of the Czech and Slovak Federal Republic I would like to express our satisfaction that the European Seismological Commission has accepted the invitation to convene in Prague, the first time ever during its whole existence.

We are well aware that this is indeed one of the few organisations which did not admit, during the many years of confrontation between East and West Europe, the interruption of scientific communications, and thus played a considerable part in integrating the efforts of our seismologists into the Pan-European context. I am glad that our seismologists have been accepted by the European scientific community, and that they were thus able to contribute to the advancement of this important branch of science. Their long years of scientific activity are now culminating in Prague, playing host to the only representative body of European seismologists.

Allow me to remind you of the importance of broad international co-operation in relation to our science policy. We are now going through a period of transforming our whole society which should follow the democratic and Christian traditions of the European continent. It was indeed science which always integrated Europe into a unique association of people professing the principle of truth and humanity. It is incumbent upon this Government to support these traditions and promote them with its science policy. This year our Parliament passed a new bill on science which, albeit not perfect, guarantees freedom of scientific work, and provides a constitutional basis for its support by the establishment.

Ladies and gentlemen, I would like to make use of this occasion to thank you all for the confidence you are investing into the evolution of Central Europe. Your exceptional interest in taking part in this General Assembly is sufficient proof thereof. I am convinced that the Czech seismological school will not fall short of your expectations, and that this General Assembly will provide the scope for an extensive exchange of opinions, and be a significant contribution to the development of seismology, a science whose colours always bear the symbol of work for the well-being of mankind. I sincerely hope your Assembly will prove successful.

Prof. J.Pacák, Vice Chancellor of Charles University, Prague

Dr. V.Hančil, Vice President of the C.S.A.S

Prof. K.Drbohlav, Dean of the Faculty of Mathematics and Physics, Charles University

Dr.V.Čermák, Director of the Geophysical Institute, C.S.A.S.

Dr.L.Waniek, President of the E.S.C.

Ladies and Gentlemen,

It is an honour and particular pleasure for me to be able to welcome the many distinguished participants and guests who have come from all over Europe to exchange information and experience at the XXIII General Assembly of the ESC held for the first time in its history in Prague.

Our attendance at the historical Carolinum, given its name after Charles IV, the King of Bohemia, the Roman emperor, and founder of the first university in Central Europe, brings back the awareness of the necessity to promote common European culture and knowledge, of the necessity to make Europe a continent of humanity and democracy. Though not very large in number, the members of the ESC have always endeavoured to put these ideas into practice.

For the benefit of those who are too young to remember allow me, ladies and gentlemen, to throw some light on the history of ESC. Fourty years ago a Pan-European body was established with the aim at fostering close co-operation among European seismologists. Thanks to their dedication for the cause, the ESC was put on a firm and enduring basis and made to resist and survive the many crucial events in the post-war history of Europe. Through their scientific and personal involvement the ESC has attained a significant level. The twenty-two foregoing General Assemblies represent valuable biannual surveys of the progress made by European seismologists.

The scientific achievements are unquestioned, however, the personal dimension given to the Assemblies is of equal importance. On those occasions we established personal contacts with colleagues pursuing the same scientific problems and made life-long friends. In contrast to the reality, there were no borders, no curtains to hinder our communication. The spirit of understanding, true tolerance, and the idea of European identity encompassing the regional peculiarities were inherent qualities of our meetings.

I think you will agree with me, ladies and gentlemen, that our Prague Assembly terminates the period which could be characterised by activities of the second ESC generation. What leads me to this conclusion? In the early fifties, our ESC predecessors laid down solid foundations to a co-ordinated seismological research in Europe. In the seventies, they handed over their responsibilities to the generation of their disciples. Unfortunately, that generation even if not stigmatised by the Second World War had to face the implications of permanent East-West confrontation. This generation is now on the brink of leaving, which is also true for me. Therefore, at this point, I wish to express my deep gratitude to all seismologists of my generation who made it possible in those times that scientific as well as personal communications went on uninterrupted.

Now the time has come for the third generation to take over and continue, under more favourable conditions, our work. The Prague meeting takes place during a new historical process which overcame artificial barriers between the countries in Europe. There is no need any longer to obey irrational unsubstantiated rules, carefully balancing everything between East and West, or to spend much effort in minimising the negative impacts due to different political systems. The fundamental conditions for integration have been formed. The idea of an integrated Europe, dreamed by the founders of the ESC, is coming true.

Under these circumstances the primary commitment of the ESC is to extend and intensify European co-operation. In the past, the differences in economic development resulted in considerable discrepancies between individual countries and were obviously manifest in seismology, as well. It is our duty now to minimise the divergence and establish an European seismology so that it can fruitfully interact with the international seismological community. The ESC is ready to proceed in this direction and provide opportunities for the growing number of its members.

Ladies and gentlemen, concluding my address, let me remind you the man who introduced Czech and Slovak seismologists into the ESC community. His name is Alois Zatopek. Those of us who had the opportunity to work under his guidance are greatly indebted to him for making clear to us the importance of the ESC for the advancement of seismology. More than seven years ago we lost our respected teacher, and the ESC lost one of its prominent leaders, being President from 1962 to 1966. Many of you will remember him as dedicated musician and gifted cellist. Therefore, consider the following musical part of our ceremony as a tribute to him.

At the end, permit me to quote the final words of Zátopek's presidential address delivered in Budapest 1964: "I believe that in the traditional atmosphere of friendship and of deep interest in essential problems, we take together a further step toward the development of our science, the results of which may serve to the benefit of the whole mankind."

Despite the last dramatic changes in Europe, his words can reflect even today the basic philosophy and principles of the ESC.

Herewith, I declare the XXIII. Assembly of the European Seismological Commission open, and wish much success to all participants.

Dr.R.Adams, Representative of I.A.S.P.E.I.

Musical intermezzo: Soloists: J.Boušková, Harp, and V.Kočí, Cello.
Music by J.S.Bach, C.Saint-Saëns, N.Rota.

Dr. P. Svobodný, Institute for the History of Charles University

Charles University and History of Science in Prague

Mister Chairman, Ladies and Gentlemen

The fact that the opening ceremony of your General Assembly is held in one of the most interesting historical buildings in Prague, is bound to prompt the question what the medieval college has in common with your field of interest, with seismology. I can state beforehand that Charles College called Carolinum, the headquarters of Prague University since 1380 up to the present day, has never been destroyed or damaged by an earthquake. There must be another link between seismology and Carolinum and it naturally exists - in the history of both of them. The history of seismology is relatively young and a lot of you are greater experts in it than I am. I will only try to give you an outline of the rich history of science in Prague, whose representatives very often worked in the rooms you are going to see after my short contribution.

The symbolical key to the history of Prague University hangs over the heads of the presidium. The tapestry, woven after the design by modern Czech artist Vladimír Sychra, bears a lot of symbols connected with the history of our university and of the respective sciences which have flourished here since the 14th century. Its central motif is taken from the oldest university seal: the founder of Prague University, Charles IV, the King of Bohemia and Roman Emperor, is passing the foundation charter and thus the fate of the university itself to the hands of St. Wenceslas, patron-saint of Bohemia. Above their heads the symbols of four original faculties are depicted. Among them, the stars with the Moon and the Earth represent the Faculty of Arts, which from the foundation of the university in 1348 until 1920, when the Faculty of Natural Sciences was added, was the centre of development of natural sciences, including physics and particularly seismology in its beginnings as a university subject.

The stars and other extra-terrestrial bodies were studied by many physicists active at Charles University, including those who belonged to the predecessors or founders of geophysics and seismology. Already during the early stage of the university existence, outstanding personalities were among its staff, namely astronomers Křišťan of Prachatice and Jan Ondřejův called Šindel. Towards the end of the 16th and the beginning of the 17th centuries, during the reign of the Emperor Rudolf II, favourable conditions were created for the development of natural sciences even outside the university, at the Emperor's court. Nevertheless, the world-famous persons of Prague Rudolphian physics, particularly astronomy, such as Tycho Brahe and Johannes Kepler, were also involved in the university life. It was the merit of astronomer, mathematician and physicist of Czech origin, professor of Charles University, Tadeáš Hájek that they were invited to the court. Another professor of the university and its rector, Martin Bacháček, a close friend and coworker of Johannes Kepler, helped him in his astronomical work by accommodating him in the university college of King Wenceslas situated just opposite the building you are now. In the garden of the college a simple wooden observatory was built for Kepler by the university. The first two laws of planetary motion derived by Kepler from astronomical observations carried out by Brahe were published in 1609 by Kepler in Prague under the title "Astronomia Nova".

After the decline of the Rudolphian centre, physical sciences were again concentrated at the university, at that time under the ideological influence of counter-Reformation Jesuit Order. The rare cases of individual scientific activity in the baroque epoch can be found in the physical works by John Marcus Marci in the 2nd half of the 17th century and by Joseph Stepling 100 years later. Professor Stepling, a progressive member of the Jesuit Order, promoted the new trend in science based on experiments and Newton's work. His organisational, pedagogical and scientific activities had a positive impact on the development of physical and mathematical sciences at the Prague University. His merit was also the scientific orientation of the University Observatory in Clementinum, which became an important establishment of the University. Meteorological and later also geophysical observations, begun and conducted at the Clementinum Observatory, represent today one of the longest series of systematic observations in the world. New activities of the Observatory initiated in the 40's of the 19th century by its new director, world-famous researcher of Austrian origin, professor of the Prague University Karl Kreil, were reflected in the denomination "the geophysical period of the Prague Observatory". During his stay in Prague, professor Karl Kreil constructed the first modern earthquake-meter, which principles were described in his article published in 1853.

At the same time theoretical physical research flourished in Prague as well. However, the development of natural sciences was no longer represented solely by Charles University, but particularly by the Prague Technical University (formed in 1806 from an earlier engineering school) and by the Royal Bohemian Society of Sciences (founded in 1784). All these three institutions were based on regional, not national principles. This, among others, means that apart from the personalities of Czech origin, especially Germans from Bohemia or other Austrian lands, on the one hand, and from the Reich itself on the other, belonged to outstanding persons of Prague scientific institutions. One of the greatest discoveries in physics made or published in the 19th century in Prague is closely connected with all the three institutions mentioned above. Christian Doppler, professor of mathematics at the Prague Technical University from 1841, described the well-known physical phenomenon, so-called Doppler effect, in 1842 in Prague. As a member of the Royal Bohemian Society of Sciences, the headquarters of which were located in the building of Carolinum, he presented his discovery first at the session of the Society, which was held in the room located then next to the Aula Magna we are sitting in just now.

An important circumstance, which influenced the orientation and organisation of scientific work during the 2nd half of the 19th century, was the Czech National Revival, including the nation's effort to build up its own educated class. An important step in the fight for independent Czech science was the division of the two Prague universities (Technical University in 1869 and Charles University in 1882), which led to the existence of quite separate institutions based on national principles. The space and inventory of Charles University were divided regardless of the fact that the Czech students were in majority. The scientific institutes followed their contemporary director: the Physical Institute, led by physicist Ernst Mach who in the 19th century was engaged in Prague, remained at the German University. After 1882 Prague German University was attractive for other outstanding scientists, like Albert Einstein or his successor to the Chair of Theoretical Physics Phillip Frank among others. Prague Czech University after its activation in 1882 and particularly after 1918, when Czechoslovakia gained its independence, very soon attained a high level in most scientific branches. Among the pioneer works of the beginnings of Czech seismology the works of professor Václav Láska, one of the first geophysicists, have had their unforgettable place since the 90's of last century.

The description of progressively developing geophysics and particularly seismology in the 20th century cannot be given by me, of course. I only tried to give you a brief historical background and point out some connections between your science and the place where your General Assembly opens. Last but not least let me wish you a successful course to your meeting using the classical words of our antique university:

Quod bonum, felix, faustum, fortunatumque sit.

Meeting of the Executive Committee

Tuesday, September 8, 1992, 16:00 - 18:00

1. Structure of the Subcommissions

The structure and changes within the Subcommissions is discussed. The outcome of the discussions are reflected in the chapter "Subcommissions".

Meeting of the ESC Council

Thursday, September 10, 1992, 18:00 - 20:00

Present: Adams, Aichele, Arefiev, Bonjer, Burton, Camelbeeck, Cara, Christoskov, Dessokey, Drimmel, Enescu, Eva, Flick, Hjelme, Kulhanek, Luosto, Makropoulos, Mayer-Rosa, Mendes Victor, Muco, Mueller, Payo, Pearce, Schenk, Sobolev, Stefansson, Waniek, Weber

1. Presence of a quorum is stated.

2. Next ESC General Assemblies

The invitation by Prof. J.Drakopoulos to host the XXIV. General Assembly 1994 in Athens is gratefully accepted by the Council. The option to hold the XXV. General Assembly 1996 in Potsdam is also acknowledged.

3. Elections

The Bureau:

L.Mendes Victor is appointed as election chairman.

The Nominating Committee presents the candidates in sequential order. Election is carried out by secret ballot for each position separately, first for the President, then the Vice-Presidents and the Secretaries.

Results of the elections:

President:	L.Waniek, Prague - unanimously re-elected
Vice President:	G.Sobolev, Moscow - unanimously re-elected
Vice President:	J.Drakopoulos, Athens (14 votes) - elected
	O.Kulhanek, Uppsala (10 votes)
Secretary General:	P.Suhadolc, Trieste - unanimously elected
Assistant Secretary:	D.Mayer-Rosa, Zürich - unanimously elected

The SC-Chairpersons

All SC-Chairpersons have been elected unanimously.

SC-A Seismicity:	K.Makropoulos, Athens
SC-B Data Acquisition and Interpretation:	L.Vinnik, Moscow
SC-C Source Physics:	A.Deschamps, Paris
SC-D Deep Seismic Sounding:	D.Luosto, Helsinki
SC-E Earthquake Prediction:	H.Berckhemer, Frankfurt
SC-F Engineering Seismology:	V.Schenk, Prague

4. Titular Members:

Former Yugoslavia is not represented any more.

According to the ESC bylaws, the business dealing with the applications of the Republics of Croatia, Slovenia and Macedonia had to be postponed to the moment, when their membership to IUGG/IASPEI is cleared. If their membership is not cleared at the next General Assembly, the Council authorises the Bureau to invite their representatives as observers (no objections, two abstentions).

The new Titular Members (see list under Opening Session: "Changes for 1992-1994") are appointed by the Council and will be presented for confirmation to the General Assembly Closing Plenary.

Closing Plenary

Friday, September 11. 1992, 17:00-18:00

1. Address by ESC President (L.Waniek)

The President thanks all participants for their contributions and the Local Organising Committee for the excellent meeting.

2. The new Bureau 1992-1994 is introduced:

President:	L.Waniek, Prague
Vice President:	G.Sobolev, Moscow
Vice President:	J.Drakopoulos, Athens
Secretary general:	P.Suhadolc, Trieste
Assistant Secretary:	D.Mayer-Rosa, Zürich

3. Confirmation of the Subcommission Chairpersons:

SC-A Seismicity:	K.Makropoulos, Athens
SC-B Data Acquisition and Interpretation:	L.Vinnik, Moscow
SC-C Source Physics:	A.Deschamps, Paris
SC-D Deep Seismic Sounding:	D.Luosto, Helsinki
SC-E Earthquake Prediction:	H.Berckhemer, Frankfurt
SC-F Engineering Seismology:	V.Schenk, Prague

4. Titular Members

The Titular Members of ESC (see page 7) are confirmed for the period 1992-1994.

5. Adoption of Resolutions

EMSC-MEDEA DATA BASE:

Considering the efforts invested in building the earthquake parameter database MEDEA, at the EMSC in Strasbourg, and the recent and strongly supportive review panel report,
ESC recommends that means be found for its continued funding with a view to developing this database as a major source of earthquake information for those requiring data for the European - Mediterranean region.

MACROSEISMIC SCALE:

Considering that the previously used versions of the MSK intensity scales need to be improved generally with respect to the clarity of definitions and criteria, to include new types of buildings, especially those with anti-seismic design features, a more cautious and critical handling of seismological and hydrological criteria,
ESC recommends the use of the new "European Macroseismic Scale 1992" (up-dated MSK-Scale, MSK-92), proposed by the ESC working group "Macroseismic Scale" in parallel to the existing scales for a time period of three years, in order to collect experience under realistic conditions, especially on the more experimental parts of the scale on vulnerability classes and engineered constructions. A final analysis should follow this test period before the scale will officially be recommended at the XXV ESC General Assembly.

EARTHQUAKE PREDICTION:

Recognising the importance of comparing results of simultaneous observations of different physical and chemical parameters,
ESC recommends: 1. definitions of specifications for standard observations of different parameters including provision for data in standard format; 2. the development of networks of regional dimensions in order to include study of long-distance precursory phenomena; 3. the development of schemes for quick and reliable data transmission to regional centres where data are made available for analysis. The Geo-Research Centre in Potsdam offers to take an initiative in this matter.

AFTERSHOCKS:

Considering aftershocks of large earthquakes may be regarded as semi-controlled seismic sources,
ESC recommends the study of these seismic sources, not only by seismological techniques but also to supplement these by observation of non-seismic physical and chemical parameters.

LOW-MAGNITUDE EARTHQUAKES:

Recognising the progress which has been made in studying the significance of low-magnitude seismicity for forthcoming stronger earthquakes,
ESC recommends to intensify such studies.

HISTORICAL EARTHQUAKES:

Considering the increased importance of historical/macroseismic data for the assessment of long-term seismicity and seismic hazard and the need for a homogeneous updated data set,
ESC recommends the organisation of a European macroseismic data bank, including the evaluation of all existing intensity data, according to standard criteria, and that the historical parts of the catalogues, namely the European catalogues, are compiled according to standard procedures by making use of an intensity data base incorporating the most recent achievements of investigation of historical events.

MICROZONATION:

Considering the importance of seismic microzonation as a fundamental tool in risk reduction,
ESC recommends the creation of a site effect data bank.

MAGNITUDE CALIBRATION:

In view of the increasing importance of broad-band observations of seismic waves in seismological practice, considering the present practice of magnitude determinations as well as the activities of the Working Groups on developing period-dependent magnitude calibrating functions, recognising the importance of consistent magnitudes for the quantification of earthquakes, realising the significance of period-dependent magnitudes of source parameters,
ESC recommends: 1. to introduce on a trial basis the HMS calibrating functions for all relevant types of waves (PV, PH, PVs, SH, SV, LH, LV) for estimation of magnitudes of Eurasian earthquakes at stations in the Eurasian continent; 2. to refine the anelasticity model of the Earth on a global and regional scale, particularly for short-periodic waves; 3. to verify the period dependent calibrating function for bodywaves by working out appropriate principle for the processing of body-wave measurements from broad-band recordings.

GSHAP:

Considering the establishment of the International Decade of Natural Disaster Reduction (IDNDR) by the United Nations (UN), the adoption of Global Seismic Hazard Assessment Programme (GSHAP) by the International Council of Scientific Unions (ICSU), the increased need to co-operate in Europe in the field of regional seismic hazard assessment and the experience ESC has accumulated through its Subcommissions and Working Groups in this field,
ESC resolves: 1. to endorse GSHAP within the geographic boundaries of ESC; 2. to establish an ad-hoc group of experts to assist in detailed planning and implementation of GSHAP within the ESC area; 3. to support the establishment of regional centres in Moscow, Potsdam and Rabat and designate 2-3 test areas; 4. to support the strengthening of the European-Mediterranean Seismological Centre (EMSC) structure to serve as a primary data collection centre.

THANKS:

Recognising the great success of the XXIII General Assembly of ESC 1992, the participants gathered in Prague express their sincere appreciation to the Geophysical Institute of the Academy of Sciences and the Faculty of Mathematics and Physics of the Charles University for hosting this meeting, and transmit their deepest gratitude to the Local Organising Committee for the excellent work accomplished in the preparation and management of this meeting, and the very pleasant social programme.

6. Proceedings and publications

All authors of oral and poster papers will have the option of publishing in the conference proceedings or in special volumes of journals. Authors will be invited with special letters.

7. The next General Assemblies

The invitation for 1994 in Athens is confirmed with thanks to J.Drakopoulos.
An invitation for 1996 in Potsdam is taken notice of with thanks to J.Zschau.

8. Closing words of the ESC President.

I want to express my thanks to all attendant colleagues from all over Europe and also to numerous friends from other continents. They contributed to the high scientific level and to the friendly atmosphere of the Assembly. In the name of the ESC, I want to express many thanks to the members of the Local Organising Committee, headed by Dr. V.Schenk, for their efforts up to the Assembly's happy end. For a ESC-President of the hosting country it is more than a pleasure if he can announce the feelings of the majority of the participants, which can be summarised by one sentence: It was a fruitful meeting.

The new elected ESC Bureau shows several important changes. Vice-President Prof. G.Nolet asked for resignation to be free for his duties in his new Oversees position. Our thanks for his work are associated with good wishes of personal well-being and further success in scientific work. We all wish the new Vice-President Prof. J.Drakopoulos, Athens, full success and express sincere thanks for inviting the XXIV General Assembly of the ESC to Athens in 1994. The ESC has also a change in the position of the Secretary General. Dr. D.Mayer-Rosa, elected Assistant Secretary in Moscow 1984, has been serving as Secretary General since 1986 (Kiel). He succeeded to continue the work of our former Secretaries General E. Peterschmitt and J. M. Van Gils. Under his assistance the ESC adapted easily to the quite new conditions in Europe. It is a well known fact that the personality of the Secretary General is ta very important "spiritus agens" in the life of our Commission. The whole European community of seismologists owes him gratitude and wishes him full success in his further personal and scientific life. Thank you, Dieter, for all you did in favour of the ESC! Our new Secretary General is Prof. P. Suhadolc from Trieste. His scientific and personal qualities guarantee successful continuation in the work of his predecessors. The good relationship of both is a good sign for the ESC, especially in the overlapping period in which both are members of the Bureau. Good luck, Peter!

In Subcommissions B, C and D new chairpersons have been elected: Prof. L.Vinnik, Dr. A. Deschamps and Prof. D.Luosto. Let us wish them a good start and success. The ESC is greatly indebted to Profs. E.Hurtig, A.Udias and C.Morelli for their long work of high repute in the chair of the respective Subcommissions.

The ESC wants to express its deepest gratitude to the Geophysical Institute of the Czechosl. Acad. Sci. in Prague and its Director Dr. V.Čermák for the invitation to Prague and for the auspices over this General Assembly. We owe very much to the generous help of the Faculty of Mathematics and Physics of the Charles University in Prague for hosting our Assembly in its campus. The ESC highly appreciates the sponsorship of Česká pojišťovna and Ivestiční banka (joint stock companies): their help enabled the participation of an increased number of students. Last not least our thanks are directed to the Swiss Reinsurance Co. for the gift of 300 books on historical earthquakes in Europe. The excellent content and look of the book attract the reader to think about earthquake hazard through the eyes of centuries.

The ESC as a commission of IASPEI has to thank not only for the close co-operation with other commissions of this body (two of them met during the Prague Assembly), but also for financial support, which made it possible to help several East European colleagues in attending this Assembly. Thanks are expressed to Greece for the invitation to Athens in 1994. The ESC is looking forward to its XXIVth General Assembly.

ESC SUBCOMMISSIONS AND WORKING GROUPS

SC-A Seismicity of the European Region

Chair: K.Makropoulos (Greece)
Vice-Chair: J.Bonnin (France)
Secretary: Z.Schenková (ČSFR)

Working Groups:

1. European Earthquake Catalogue. Responsible: J.Bonnin (France)
2. Instrumental Classification of Earthquakes. Responsible: L.Christoskov (Bulgaria)
3. Carpathian Balkan Region. Responsible: V.I.Marza (Romania)
4. Ibero- Maghrebian Region. Responsible: L.Mendes-Victor (Portugal)
5. Historical Earthquake Data. Responsible: R.Gutdeutsch (Austria)
6. Central and Eastern Europe. Responsible: Z.Schenková (ČSFR)
7. Integrated Research of Aftershock Sequences. Responsible: S.Arefiev (Russia)
8. Volcanism and Earthquakes. Responsible: R.Schick (Germany), B.Martinelli (Switz.)
9. Seismotectonic Analysis. Responsible: C.Eva (Italy)
10. Statistical Models of Earthquake Occurrence. Responsible: G.Papadopoulos (Greece)

Activity Report:

The SC-A organised a symposium with four sessions during the General Assembly in Prague, 7.-12.Sept., 1992, with 50 oral and poster contributions. The number of submitted abstracts was equal to 73. The symposium concluded with a business meeting where the activities of the WG's of SC-A were presented and discussed, as follows:

WG-1: No progress report

WG-2: No progress report

WG-3: No progress report

WG-4: Several activities were reported mainly in the improvement of seismic networks in Spain and Portugal, the publication of a historical and instrumental earthquake catalogue for Portugal and adjacent areas, the continuation of interpretation of data collected during the EC ILIHA project, the implementation of seismotectonic studies in the area of the Azores Triple Junction, the participation of Spain and Portugal in the EC EPOCH project for earthquake prediction, and the publication of the Seismotectonic Map of Iberia. A future activity will be the re-evaluation of earthquake catalogues of this area.

WG-5: Contributions to the poster session in Barcelona 1990 have been published in the Proceedings. A book on "Historical Earthquakes in Europe" by J. Kozák (published by Swiss Reinsurance Co., 1991) and a "Monograph on Historical Earthquakes in Central Europe" by E. Oeser, U.Eisinger, R.Gutdeutsch, C.Hammerl and G.Grünthal (published by Geological Survey of Austria, 1992) has been published. Further volumes are planned. During the Assembly in Prague 18 oral and 3 poster contributions were presented. It has been generally accepted that the WG should concentrate on methods how to gain the information of seismic intensity from historical sources.

WG-6: According to the resolution no 13 in Barcelona, the Working Group proposed to continue the systematic studies of the recent seismicity on the territory of Central and Eastern Europe. A catalogue of earthquakes for the period 1981-1985 including the unification of magnitudes and fault plane solutions was prepared. Special attention was devoted to the strong earthquakes Vrancea 1986, Strazica 1986, West Bohemia/Vogtland 1985/86 and Berchida 1985. Maps of isoseismals of earthquakes felt on the territory of several countries were compiled.

WG-7: A monograph on the Spitak, Armenia 1988 earthquake is published in Russian and under preparation is the English translation. Data were collected with broad international cooperation (Russia, France, Great Britain, Switzerland, USA) from field investigations after the strong earthquake of 1991 in Racha, Georgia. The processing of these data is under way. A report on strong motion records collected for the aftershocks was published in 1991 (joint authorship IPE Moscow and ETH Zürich).

WG-8: A workshop has been organised. A detailed progress report is expected.

WG-9: This WG has been involved in the compilation of historical and instrumental seismicity and focal mechanisms along the EGT. N.Pavoni expressed his wish to resign and proposes C.Eva as new chairman.

WG-10: Since its establishment in Barcelona, 1990, this WG has developed several activities. The WG organised its first workshop in Athens on 27.-29. Nov., 1991. During the Assembly in Prague 1992, 8 contributions were presented orally or as a poster. The number of submitted abstracts was 13. The session concluded with a business meeting, where decisions are taken to organise the second workshop of the WG in Cephalonia, Greece, 2.-5 June, 1993, and a special session within the frame of the EGS General Assembly, 3.-7 May, 1993, in Wiesbaden. Decision was also taken to examine possibilities for preparing a compilation of recent bibliography on statistical seismology and for circulating a newsletter. The continuous communication among interested scientists between the Barcelona 1990 and Prague 1992 meetings contributed very much to the promotion of the WG activities.
(K.Makropoulos)

SC-B Data Acquisition, Theory and Interpretation

Chair: E.Hurtig (Germany) will be replaced by L.Vinnik (Russia)
Vice Chair: H.Aichele (Germany)
Secretary: B.Dost (The Netherlands)

Working Groups:

1. Instruments. Responsible: M.Schmidt (Germany), joined with WG 3
2. Standardisation and Interpretation. Responsible: N.Kondorskaya (Russia)
3. Data Collection and Processing. Responsible: M.Cara (France)
4. Microseisms. Responsible: E.Hjortenberg (Denmark)
5. Theory of Seismic Wave Propagation. Responsible: I.Pšenčík (ČSFR)
6. Complex Interpretation of Geophysical Fields. Resp.: V.Babuška (ČSFR) — deleted
7. High Pressure Physics. Responsible: V.Kalinin (Russia) — deleted
8. History of Seismometry: Responsible: G.Ferrari (Italy)

<u>Activity Report 1990-1992</u>

The Subcommission was very active in organising symposia and meetings during the General Assembly in Prague. The Symposium S3 is co-convened by Dr.Babuška (WG "Complex Interpretation"). Six Subcommission symposia are prepared by the Working Groups.

In the time period since the Barcelona General Assembly the Working Groups have organised meetings and workshops for discussing recent problems of seismological research.

WG-1: The current problems of broad-band seismometry are more or less solved by seismometers like STS-2, displacement transducers with large dynamic range and high resolution, force-balance feed-back configurations, 24 bit A-D-converters, and network projects like the German "Regional-Net". It could be proved that the developed systems are capable to fulfil the current needs in seismology. The efforts in designing new instruments have shifted to the development of special systems so far not available from industrial production: e.g. temperature-resistant (up to 300 °C) borehole seismometers for application in very deep boreholes (e.g. Continental Deep Drilling Project in Germany).

Taking into consideration that high-level seismometer systems for seismological observatories are commercially available and that further investigations can be shifted from developing instruments to system and data acquisition, it is recommended that:

-The working group "Instruments" and "Data Collection and Processing" should be merged into one working group.

-in order to improve the quality of seismic data and to compare quantitatively the data gathered at the single stations/observatories it seems necessary to standardise the procedures for determining the parameters of seismometers and to standardise testing and calibration techniques.

Therefore a workshop on "Standardisation of Testing and Calibration Techniques" should be organised with the aim to give recommendations to all seismological observatories.

WG-2: The WG activities were principally directed toward improvement of the earthquakes foci parameterisation on the basis of the data from various national surveys of European countries and neighbouring regions (Turkey, Greece, Czechoslovakia, Bulgaria, Romania, the former USSR regions etc.) and also from international agencies (ISC, EMSC). As far as the hypocenter problem is concerned the main attention was paid to implementation of reasonable estimates of the accuracy of parameter determination on the basis of catalogue data from analogue stations.

Concerning the dynamic parameters the studies were directed to:

- Elaboration of a homogeneous magnitude system for the Eurasian continent (Distance > 20 °), implementation to practice of the - finally to the common level reduced - calibration functions for the PV, PM, SV, SM, LV, LM phases, recorded with medium-period instruments and for the PV phases recorded with short-period instruments.

- Development of the procedure of spectral magnitude estimation (in co-operation with IASPEI WG headed by S. Duda and T. Yanovskaya).

- Development of the procedure of magnitude estimation with respect to the coda.

- Elucidation of regional peculiarities of the earthquake energy estimation on the basis of regional and local network data. Reports presented at the Barcelona symposium were made ready for publication (Pearce). The programme of the workshop for the Prague ESC General Assembly "Parameterisation of European earthquakes: recent results" was compiled.

Proposal for future goals:

- Compilation of the national catalogues in unified format in line with general international principles.

- Introduction of source parameters for strongest earthquakes in unified format (magnitudes in different types of waves, seismic moment, focal plane solution etc.) into seismological practice and unified catalogues.

- Implementation of the new unified parameterisation into seismological practice using standard and digital data.

WG-3: The WG has organised a good and permanent contact among the members of the WG representing digital station networks, national and international data centres in Europe. The development of different station networks has proceeded further, especially of MEDNET, GEOSCOPE and the broad band network in Germany. There is established a close contact of the stations and networks to the ORFEUS and the EMSC. The ORFEUS-centre has concentrated on distribution of data on CD-ROM and on the introduction of the standardised SEED-format into seismological practice as well as on the development of the corresponding software.

The WG has prepared a symposium at the recent ESC-General Assembly.

Evidently there is an increasing discrepancy between the density and quality of seismological stations and networks in Western Europe and Eastern Europe including the Balkan region. The WG should therefore concentrate its attention on possible ways to overcome this situation. The co-operation between the WGs "Instruments" and "Collection and Processing" should be improved.

WG-4: A special Issue of Physics of the Earth and Planetary Interiors was published in October 1990 with the title "Microseisms caused by factors internal and external to the earth's crust". It contains 7 papers originally presented at the IASPEI, 24. General Assembly in Vancouver 1987, and 9 other papers and was edited by E.Hjortenberg and A.N.Nikolaev.

A further investigation identifying microseisms caused by storms in Mid-Atlantic was published by J.Darbyshire in 1991 in the same journal. At an administrative session held by the Working Group in Copenhagen, May 12, 1992 various proposals for Working Group activities were discussed.

It was agreed that the following should be investigated in addition to the classical problem of microseisms:

(1) Localising areas of origin of ocean microseisms and discrimination between them on the basis of spectral and polarisation characteristics.

(2) Localisation and identification of various natural and artificial sources of seismic noise by means of analysing the frequency-velocity-polarisation-directionality and coherence patterns of the noise field in a broad frequency range (e.g. 0.001 - 50 Hz) depending on time, space, underground and environmental conditions. In particular the high frequency end is not so well documented.

(3) Systematic investigation of how various types of noise varies in relation to: a) site location (global variation, barrier and attenuation effects), b) site conditions (microzonation), c) time (seasonal variation), d) depth

The instruments proposed for these investigations are portable arrays and portable three-component stations. When such instruments are moved around in an area it is important that the instrumental noise is at least 10 dB below the minimum natural noise in the frequency range considered.

In order to study the annual variation of seismic noise several years are necessary to establish to what extent the variation is repeatable year after year.

A Symposium on Seismic Noise and Signal Detectability is scheduled in Prague at the XXIII General Assembly of the European Seismological Commission 7-12 September 1992, a continuation of a similar symposium held in Barcelona at the XXII General Assembly in 1990. It is planned to present at the symposium results of investigations of seismic noise which cover a very wide frequency range, for recordings made in Europe and Iran. A study of the annual variation of amplitude and polarisation of microseisms in Greenland will also be presented. There is an intention to extend this study to cover the entire Arctic region. We encourage such a large scale study.

WG-5: The working group continued in the former style of co-operation based on mutual exchange of pre-prints, reports, papers and computer programs which is done on distance or by personal meetings. The main topics of the group are unchanged, they correspond to those listed in the activity report of the SC-B for the Barcelona meeting. In addition, some of the members concentrated recently on the following new topics: Seismic body wave propagation in inhomogeneous anisotropic media and Finite difference travel time computations. At present, the WG is preparing SC-B1 symposium Numerical modelling in three-dimensional media. There are more than 20 accepted contributions.

WG-6: The main activity of this working group was to prepare and organise the Symposium S3 "Three-dimensional Structure of European Lithosphere-Asthenosphere Systems" in co-operation with Subcommission-D.

Future goals of SC-B and the WG's: Future goals and possible structural changes of the Working Groups (and possibly of the whole SC-B) resulting from the recent changes in Europe will be one of the topics of an informal meeting of the working groups during the ESC Assembly in Prague.

(E.Hurtig)

SC-C. Earthquake Source Physics

Chair:	A.Udias (Spain) will be replaced by A.Deschamps (France)
Vice Chair:	I.Trifu (Romania)
Secretary:	E.Buforn (Spain)

Working Groups:

1. European Focal Mechanisms Catalogue. Responsible: E.Buforn (Spain) deleted
2. Laboratory studies of fractures. Responsible to be nominated new

Activity report 1990-1992:

The chairman opens the session with a short report about the activities of the Subcommission in the past two years. The main activity was the publication of the monograph " Source Mechanism and Seismotectonics", that has appeared in a special issue of Pageoph, Vol.136, no.4 and in book form (Birkhäuser Publ.). This monograph contains the papers presented in the workshop of El Escorial (1990) and the regular session of the SC in the ESC XXII. General Assembly in Barcelona (1990). The Subcommission has organised two symposia in the Prague meeting on "Study of Seismic Sources - Theory and Observations", and "Seismotectonic Analysis: Application to Europe". There is an offer for the papers to be published in Tectonophysics.

An important progress in the study of the theory and determination of the mechanism of earthquakes in Europe has taken place in the last years. Specially there has been progress in the study of the focal mechanism of small earthquakes at short and regional distances using empirical Green functions to solve the problem of propagation in very heterogeneous media.

Methods of determination of the mechanism use inversion of the seismic moment tensor and waveform analysis. Considerable progress has taken place also in regarding to the application of these methods to earthquakes of small to moderate magnitude in European active regions.

The chairman states that he has held this position for more than ten years and it is time to renew it, nominating A.Deschamps, Institut de Geodynamique, CNRS, Valbonne, France for the chair. A.Deschamps accepted the nomination and it was approved. It was also approved that persons for the Vice-Chairman and Secretary position should be proposed by the new Chairwoman.

The Subcommission must preserve its identity as a consequence of the importance of the studies of the source of earthquakes. It must work in order to foster laboratory experiments related to the fracture process. It may concentrate on the study of source mechanism of earthquakes in Europe, the state of regional stresses and tectonic model for this region.
(A.Udias)

SC-D Deep Seismic Sounding

Chair:	C.Morelli (Italy) will be replaced by D.Luosto (Finland)
Vice Chair:	B.Guterch (Poland)
Secretary:	C.Prodehl (Germany)

Working groups:

1. Synthesis. Responsible: V.Sollogub (Russia), C.Prodehl (Germany)
2. Region N-Europe. Responsible: M.Sellevoll (Norway), C.Lund (Sweden)
3. Region SW-Europe. Responsible: P.Giese (Germany), A.Hirn (France)
4. Region E-Europe. Responsible: K.Posgay (Hungary)
5. Deep Reflections. Responsible: K.Fuchs (Germany)
6. Phase Velocity Field in Europe: Responsible: T.Yanovskaya (Russia)

<u>Activity Report 1990-1992</u>

The results performed in DDS experimental activity in the period 1990-92 are condensed in the abstracts prepared for the Prague meeting.

But the main contribution are coming from Experimental Petrophysics and Superdeep Drillings.

Petrophysics: Mengel and Kern (1990, 1991), continuing the 10 years researches published by Kern (1982), have confirmed that over a range of constant confining pressure up to 6 kb and temperatures ranging from 20-750 °C, in igneous and metamorphic rocks typical for the crust and mantle Vp is only roughly related to densities. The dehydration reactions in some Basalts cause a significant abrupt and irreversible drop of P- and S-wave velocities around 350 °C. The velocity declines are attributed to spontaneous lowering of effective pressure due to internally-created pore pressure that induces opening of pore spaces and reconstitution of pore geometry.

One of the consequences is that the expanded rho-h law by Mengel and Kern open new possibilities to get better gravimetric models from accurate DSS results.

Super-Deep Drillings: Pavlenkova (Terra Nova 4, 117-120, 1992) has given new interesting data on the Kola results. The absence of the Conrad discontinuity expected at 9000 m and the existence of new sub-horizontal reflectors not indicated by DSS, have been interpreted as a demonstration that not always the seismic discontinuities correspond to lithological or tectonic boundaries, but on the contrary may depend from changes in the physical conditions of the rocks like porosity, anisotropy of the seismic velocities, and also the drill-hole diameter, which characterises the rocks tensions and the pressure variations.

The seismic wide-angle reflection data, obtained in the region of the hole, revealed also a sub-horizontal boundary at a depth of 7 km of uncertain origin. Core sampling implies that this boundary is associated with a change in core pressure, with higher porosity and with velocity anisotropy.

The situation of the DSS 1950-1990 extensive profiles (1500 km), connecting all the super-deep and deep drillings and the major geological provinces in Northern Eurasia has been discussed by Benz et al. (EOS.73, 28, 1992). Depending on the region of interest and the types of sources used DSS profiles range from 200 to nearly 4000 km in length.

Beginning in the early 1970s, the DSS program routinely used nuclear explosions in the recording of ultra-long-range profiles. About half of the 115 "Peaceful Nuclear Explosions" detonated since 1966 have been associated with the DSS program.

A variety of analogue seismic recording systems have been used by Soviet geophysicists for collecting DSS data. Early seismographs used oscillographs to make permanent photographic records of the seismic waves or arrivals. From 1950 to 1970, approximately 50.000 km of profiles were recorded in this manner, resulting in approximately 200 land and off-shore DSS profiles. In 1970, the fotographic instruments were replaced by modern analogue systems that recorded on magnetic tape. Despite recent economical and political difficulties in the CIS, the DSS program is continuing to develop and improve. The area of Eurasia covered by DSS profiles comprises roughly 15 % of the total continental land mass.

A.S.Alekseev and N.I.Pavlenkova raised concerns about the preservation of the DSS data during recent visits to the United States. The analogue media used to record the DSS data are threatened to be unrecoverable without restoration in the near future. Efforts are being made to gain access to more of these unique data so that they can be permanently stored in a digital format easily accessible to the geophysical community.

In agreement with ESC Resolution 12 (DSS Data Base) in Barcelona all the DSS profiles in Italy 1956-1986 have been collected, digitised, reprocessed and re-interpreted. The results will be presented at a CNR meeting on CROP in Rome, Sept. 15, 1992.
(C.Morelli)

SC-E Earthquake Prediction Research

Chair: H.Berckhemer (Germany)
Vice Chair: G.Sobolev (Russia)
Secretary: A.M.Isikara (Turkey)

Working groups:

1. Precursors. Responsible: G.Sobolev (Russia), T.Chelidze (Georgia)
2. Field Observations and Techniques. Resp.: J.Zschau (Germany), A.Prozorov (Russia)
3. Algorithms and Models. Responsible: G.Purcaru (Germany)
4. Man-made Earthquakes Responsible: P.Knoll (Germany) new

<u>Activity report 1990-1992</u>

During the XXII General Assembly of ESC in Barcelona, SC-E convened a one day symposium on earthquake prediction research in which 18 papers were presented. Eight of them will be published in the proceedings of the Assembly.

In the evening of the same day SC-E invited to an open meeting on procedures for issuing earthquake predictions to the public. The outcome of a thorough and fruitful discussion was expressed in two resolutions which were later adopted by the delegates. The first appeals to the responsibility of scientists in conveying predictions to the public. The second was an offer to the Council of Europe for assistance in establishing a European scientific evaluation committee for earthquake predictions. The full text of these important resolutions may be found in the proceedings of the Barcelona assembly.

The resolutions had also been prepared in view of the "International Conference on Earthquake Prediction: State-of-the-Art" held under the auspices of the Council of Europe and the "Open Partial Agreement on Major Disasters" in Strasbourg, October 1991. The chairman and members of the SC-E were involved in the organisation and contributed to the scientific programme. From 58 reports presented a rather comprehensive picture of our present knowledge arose. Among others it was recommended to establish a European data bank on seismicity precursors, and to identify multi-disciplinary observations of physical fields in test areas. At the end of the conference, after a long and partly controversial discussion, a "Code of Ethics" for earthquake prediction was drafted. Again, ESC offered its professional advice to the Council of Europe.

On April 1991 the chairman of SC-E was invited to a regional conference on Earthquake Prediction and Seismic Risk in Alicante, Spain which showed impressively the increasing research activities in Spain.

The high social relevance of the scientific background of natural hazards and risks was demonstrated by a "Research Conference" of the European Science Foundation on "Natural and Anthropo-Genetically Induced Hazards" held in Davos, Switzerland, December 1991. The SC-E chairman was invited to lecture on the problems of earthquake prediction.

In 1991 the second phase of the EPOCH programme on Climatology and Natural Hazards supported by the CEC in Brussels came into action. Colleagues of several European countries are participating. Centres of research activities for earthquake prediction studies are Central Italy and Greece. A fruitful first co-ordination meeting took place in Athens in June 1992. EPOCH will be followed by the new research programme "Environment".

SC-E Working Group 4 on "Induced Seismicity" is organising a workshop during the International Symposium on "Mining Induced Seismicity", 14.-18. September 1992 in the Liblice Castle near Prague.
(H.Berckhemer)

SC-F Engineering Seismology

Chair: V.Schenk (ČSFR)
Vice Chair: G.Zonno (Italy)
Secretary: T.de Crook (The Netherlands)

Working Groups:

1. Macroseismic Scales. Responsible: G.Grünthal (Germany)
2. Near-field Seismology. Responsible: V.Schenk (ČSFR)
3. Seismic Risk and Design Criteria. Responsible: P.Burton (U.K.)
4. Microzonation. Responsible: M.Marcellini (Italy)
5. Expert Systems and Seismic Risk Mitigation. Resp.: G.Zonno (Italy), M.Garcia (Spain)
6. Macroseismology. Responsible: M.Stucchi (Italy) new

Activity Report 1990-1992

The main activity of the *first WG "Macroseismic Scale"* for the past four years was connected not only with the up-dating of the present MSK-scale according to needs of recent seismological practice but also with its modification with respect to engineered buildings. After the first WG Meeting in Zürich, 1990, the second Workshop of the WG was held in München, 1991 (sponsored by the Bayer. Reinsurance Company) and the third one was organised in Walferdange, Luxembourg, under the auspices of the European Centre for Geodynamics and Seismology. The prepared new version of the "European Macroseismic Scale" will be presented during the XXIII. ESC General Assembly in Prague. The scale consists of (a) the Core Scale, (b) the "historical earthquake" annex, (c) the "seismogeological effect" annex, and (d) the "engineered building" annex. The scale is assumed to be completed by "Introduction", "Guidelines for users", "Glossary" and "Pictures of buildings together with their structure damages". Specialists of Czechoslovakia, France, Germany, Hungary, Italy, Moldovia, Switzerland and the Union of Independent Countries took part in the compilation of the new macroseismic scale under the chairmanship of Dr. G.Grünthal (Germany) and the Secretary of the WG Dr.R.M.W.Musson (UK).

The activity of the *second WG "Near-field Seismology"* was concerned with numerical processing of digitized strong ground motion time histories and inclusion of the obtained results into present strong-motion data banks. Common correlations between strong motion parameters and macroseismic intensity were also presented. Statistical tests based on the multidimensional linear regression and one-factor discriminant analyses allow strong ground motion records with a minimum of 70% efficiency with respect to macroseismic intensity to be classified. Some other results which were obtained in the interpretation of strong and weak ground motions will be presented during the General Assembly Symposium S2.

Activities of the *third WG "Seismic Risk and Design Criteria"* were concentrated on two main topics: a) compilation of a handbook on "The Practice of Seismic Hazard Assessment" for most earthquake active countries over the whole world, and b) application of and testing new methodological approaches and computational techniques in hazard assessments.

As to the first topic, in collaboration with the IASPEI Subcommission "Earthquake Hazard", approximately 70-80 summaries on earthquake hazard calculations of earthquake active countries have been collected. The volume will be published in the next future in the form of a handbook on "The Practice of Seismic Hazard Assessment". Each summary contains concise information on: i) the history of earthquake hazard evaluation in a given area, ii) the survey of the methods used for the earthquake hazard calculation together with maps of earthquake epicentres, of maximum macroseismic observations and of earthquake hazard, iii) the research organisations and companies interested in this topic, and iv) the future activity in this field.

In this joint IASPEI-ESC Project all countries situated in and close to earthquake areas were divided into the following regional blocks: - North, Western and Eastern Europe, - North, Central and South America, - Near, Middle and Far East, - North Africa and Africa, - Pacific area.

Under the second topic of the third WG a meeting on "Characteristic Earthquakes and Seismic Hazard" was held in November 1990 at the Liblice Castle, Czechoslovakia. Other results in methodology and application are presented during the General Assembly Symposium SC-F.

When the *fourth WG "Microzonation"* started in 1989, two principal activities have been identified: a) preparation of a review of seismic microzonation studies in Europe with the final goal of developing a microzonation methodology relevant to European countries, and b) participation of the WG in a microzonation test site in Armenia. For obvious reasons it was not possible to achieve the second goal (but still the need of a common project does exist).

The state-of-the-art in microzonation in Europe may be summarised as follows: different methodologies, different approaches, sometimes wrong approaches. This finding is evidenced by the

"First Seismic Microzonation Review Progress Report", and lead the fourth WG to the conclusion that is useless to define a common methodology without a foregoing analysis of those discrepancies. The WG therefore decided to continue in collecting critical contributions from the representatives of the WG countries. Each contribution includes a list of all the microzonation studies performed in the country and information on each microzonation: goal of the microzonation, authors (persons and institutions), methodology adopted, data employed for the analysis, final results. These "second generation reports" include contributions (author's names are in parentheses) from Algeria, Austria (G.Duma), Belgium (O.Jongmans), Czechoslovakia (Z.Schenková), France (P.Y.Bard, J.L.Durville, J.P.Meneroud, P.Mouroux), Greece (G.Tselentis, I.Vassiliou), Italy (A.Corsi, T.Crespallani, E.Lentini, A.Marcellini, A.Zapone), Rumania (N.Mandrescu), Spain (C.Lopez Casado, J.Morales, J.Chacon Montero).

The *fifth WG "Expert Systems and Seismic Risk Mitigation"* has organised under the auspices of the European Centre for Geodynamics and Seismology (ECGS) the third Workshop "Application of Artificial Intelligence Techniques in Seismology and Engineering Seismology" in Walferdange, Luxembourg, during March 23-25, 1992. A substantial support of the ECGS allowed many scientists from Europe to participate in the meeting. Most of the presented papers will be published in the Proceedings (Cahiers du Centre Europe de Geodynamique et de Seismologie, vol.6, Luxembourg 1992). For the future of the WG it was proposed to create different task groups which will focus on specific topics, e.g. seismic signal analysis, neural network applications, vulnerability, earthquake prognosis, seismic classification, etc.

In 1992, M.Stucchi (Italy) proposed to establish a new *sixth WG on "Macroseismic Data"*, covering the area between historical investigations of earthquakes and the parametric catalogues. He proposed the following goals for that WG: (a) to review and improve the procedures which are currently followed from the historical investigation to the assessment of intensity and to the determination of earthquake parameters, and (b) to formulate recommendations for the preparation of a uniform macroseismic data set on European level. To achieve these goals, the WG is supposed to collaborate closely with some other ESC WGs such as "Historical Earthquake Data", "Catalogue", "Macroseismic Scale". The ESC Bureau recommended to establishing the new WG under SC-F during the XXIII. General Assembly in Prague.
(V.Schenk)

ESC BYLAWS

(adopted in Sofia 1988)

Article I. Purpose of the Commission

The European Seismological Commission (ESC) promotes seismological studies and projects in Europe, including all countries near the Mediterranean Sea and encompassing the area from the Mid Atlantic Ridge to the Ural Mountains and from the Arctic Ocean to North Africa.

The ESC was created in 1951 by the International Association of Seismology and Physics of the Earth´s Interior (IASPEI) and is a regional commission of IASPEI. Administrative and scientific decisions should be consistent with the general rules / decisions of IASPEI.

Article II. Membership

Each country that adheres to IASPEI and is situated within the region defined in Article I is a member and has the right to nominate a national representative to the ESC, referred to as a "Titular Member". Titular Members should be nominated by the national committees of IASPEI / IUGG. If no candidate is nominated by the national committee, the Bureau may propose a candidate to the appropriate national organisation. They are appointed for two successive administrative periods and may be re-appointed thereafter.

Titular Members are responsible for: a) The votes on behalf of their country; b) The national reports requested by the ESC; c) The dissemination of ESC information and announcements on a national basis In the case of absence from a General Assembly, a Titular Member may delegate his duties to a compatriot present at the General Assembly or to a member of the Bureau. If a Titular Member fails to fulfil the duties described in Article II of the Bylaws, the ESC Council may approach the national committee to nominate a new member.

Article III. The General Assembly

A General Assembly is the time period from the opening plenary meeting through the closing plenary meeting. Scientific sessions and administrative meetings are scheduled during the General Assembly.

The ESC Council decides the location of the next General Assembly. If no decision is reached by the Council, the choice of a place and date is left to the Bureau. The letters of convocation for a General Assembly shall be sent to all members of the Council at least three months before the date chosen. An extraordinary General Assembly must be called by the Bureau if requested by the President or by at least one third of all Titular Members.

Article IV. The Council

The ruling body of the ESC is the Council, consisting of the Titular Members, the members of the Bureau and the Executive Committee.

The Council meets at least once during every General Assembly for elections. Before the closing plenary meeting, the Council shall decide on: 1. Date and place for the next General Assembly, based on invitations received; 2. Resolutions forwarded by the Resolutions Committee; 3.Other matters referred to the Council. All decisions are announced at the closing plenary.

Article V. The Bureau

The administrative body of the ESC is the Bureau, consisting of: the President, the immediate Past-President, two Vice Presidents, the General Secretary and the Assistant Secretary. The Bureau is elected by the Council at each General Assembly.

The President is eligible for re-election once only, the Vice-Presidents twice only and the General Secretary without restriction. The immediate Past-President is a member by right of the Bureau for one administrative period. The Assistant Secretary is responsible for the organisation of the next General Assembly and serves for one administrative period. A country cannot be represented by more than one person in the Bureau.

Article VI. The Executive Committee

The members of the Bureau and the chair-persons of the Subcommissions form the Executive Committee. It meets at least once during the General Assembly and at other times if necessary. It advises the Bureau in the preparation and the co-ordination of the General Assemblies. In addition it intervenes in any important question at the initiative of the President or of at least one third of its members.

The International Association of Seismology and Physics of the Earth's Interior (IASPEI), the European-Mediterranean Seismological Centre (EMSC) and the European Association for Earthquake Engineering (EAEE) are represented in the Executive Committee.
The decisions of the Executive Committee must be confirmed or rejected by the Council.

Article VII. The Committees

Resolutions Committee: At the opening plenary meeting of each General Assembly, the president appoints a Resolutions Committee consisting of one member of the Executive Committee and at least two other members. All resolutions presented to the Council for decision must be transmitted in writing to the Resolutions Committee not less than 24 hours before the said meeting. The Resolutions Committee is responsible for wording the resolutions to conform with the terminology of IASPEI and IUGG. The Committee shall post all resolutions and recommendations at least 12 hours before the closing plenary meeting.

Nominating Committee: The president appoints a nominating committee consisting of not more than four members. This committee must be approved by the Executive Committee at the first business meeting of each General Assembly. The Nominating Committee proposes nominees for positions in the Bureau. Members of the Nominating Committee are ineligible for membership in the Bureau.

Other committees: The president may appoint other committees to propose solutions for specific administrative problems.

Article VIII. The Subcommissions

Subcommissions are formed within the ESC for the study of particular scientific problems. Subcommissions can be formed or dissolved by decision of the Council on the recommendation of at least three members of the ESC. Subcommissions are administered by special internal regulations.

Article IX. The Working Groups

Working Groups form part of a Subcommission and follow their internal regulations.

Article X. Administrative Period
The administrative period, normally two years, comprises the time interval between the closing plenary meetings of two consecutive General Assemblies.

Article XI. Elections

The Council elects the Bureau, the chair-persons of the Subcommissions and confirms the Titular Members. A country cannot have more than three votes nor can a person have more than one vote by reason of his different offices. Vote by proxy is allowed.

The election of the President, the two Vice-Presidents and the other members of the Bureau is carried out successively. In general, voting is by secret ballot. In cases of a foreseen unanimity, voting may be executed by show of hands.

All decisions by the Council will be made by a simple majority of the eligible votes cast. In case of a tied vote, the President's vote is decisive. For cases other than election of the Bureau, voting by secret ballot is performed only if requested by at least one member.

A Titular Member may cast his vote in written form forwarded by mail.

Article XII. Amendment of Bylaws

Drafts of proposed amendments must be made available to all members of the Council prior to the General Assembly. They must be approved by two thirds of all members of the Council. If a quorum of two thirds of all members of the Council is not obtained, the same amendments may be approved by two thirds of members present during the next General Assembly.

Article XIII. Interpretation of the Bylaws

The English text is the guide for the interpretation of the Bylaws. In case of any ambiguity, the statutes of IASPEI will serve as a reference.

Article XIV. Approval of the Bylaws

The text of these Bylaws has been approved by the ESC Council at the General Assembly on 26. August 1988.

INTERNAL RULES FOR THE SUBCOMMISSIONS

I. Membership and Administration

Everybody interested in the objectives of a Subcommission is qualified for membership. Each Subcommission is administered by a Bureau consisting of a President, a Vice-President and a Secretary.

II. Obligations

The President of a Subcommission is responsible for: 1. The delivery of activity reports of the Subcommission to the ESC General Assembly; 2. The announcement of the results and decisions taken by the Subcommission to the ESC Bureau; 3. The timely forwarding of resolutions to the Resolutions Committee. The proposed resolutions or recommendations shall concern scientific matters only.

III. Composition

The composition of a Subcommission, in particular the establishment and termination of specific Working Groups, is decided by the Bureau of each Subcommission.

IV. Dissolution

The dissolution of a Subcommission may be pronounced by the ESC in the following cases:
1. On the justified proposition of the President of the Subcommission.
2. If the Subcommission has not been active during the past two administrative periods.

V. Modifications of the Internal Rules

Internal rules of the Subcommissions may be modified by decision of the ESC Council at a General Assembly of ESC.

PART II.

PROCEEDINGS

The Roermond earthquake of April 13, 1992. Preliminary investigation using data from the seismic network in Belgium and G.D. of Luxemburg.

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On April 13, 1992 at 1h20m (UT), a significant earthquake occurred in the Lower Rhenish Embayment in the vicinity of the city of Roermond in The Netherlands. The earthquake was strongly felt in the border region between The Netherlands, Belgium and Germany. In the epicentral area, it caused damages corresponding to the degree VII in the M.S.K. intensity scale. The macroseismic map for the belgian territory is presented on figure 1.

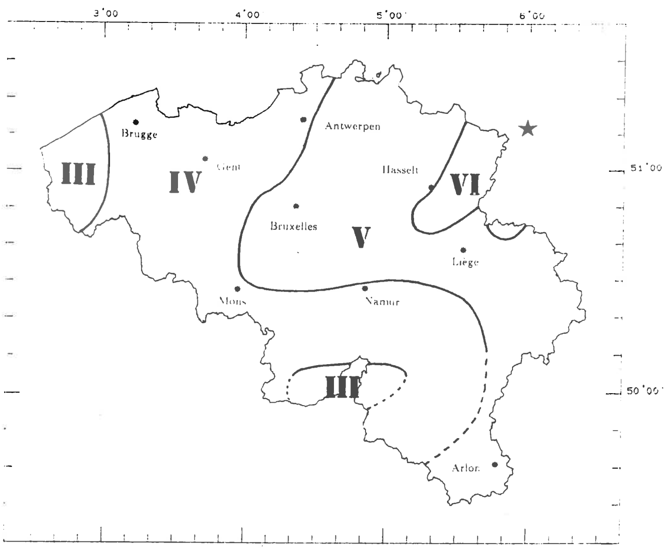

Figure 1. Macroseismic map (M.S.K. scale) for the Roermond earthquake.

Using P- ans S-waves arrival times from 40 stations at less than 200 km, the earthquake location is:

Origin time: 1h20m 2.5s ± 0.3s
Latitude N: 51° 10.9' ± 0.8 km
Longitude E: 5° 57.3' ± 0.8 km
Depth: 15.7 ± 1 km

The epicenter is indicated on figure 2.

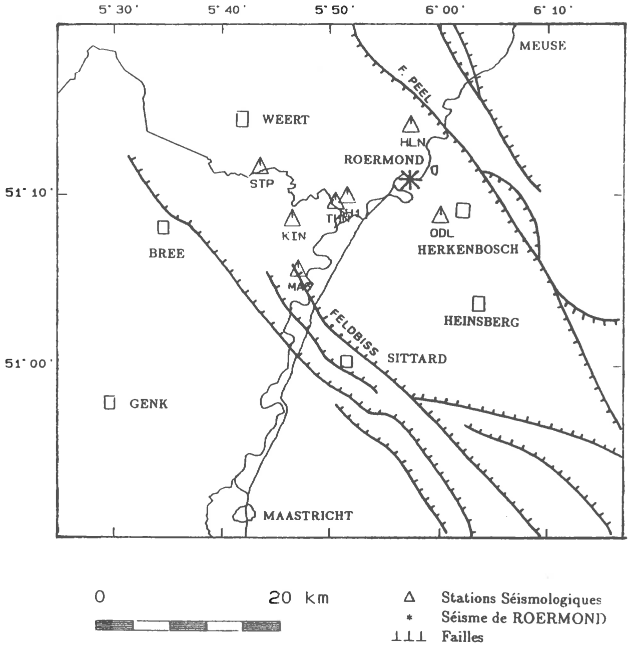

Figure 2. Map of the Roermond region.

The earthquake was recorded by 18 stations in Belgium and Grand-Duchy of Luxemburg (figure 3) with distances ranging from 40 km to 220 km. The recordings were not clipped in 7 stations. Table 1 gives the maximal ground motions measured at each of these sites.
The magnitude determined with these data is $M_L = 5.8 \pm 0.2$.

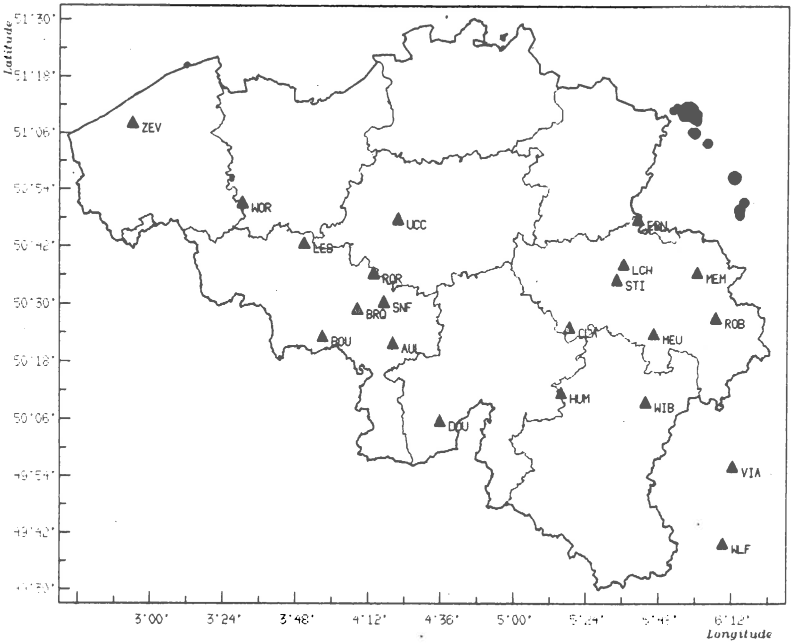

Figure 3. Location of the permanent seismic stations in Belgium and Grand-Duchy of Luxemburg. The epicenter of the Roermond earthquake and his aftershocks are presented.

Table 1.

	Δ (km)	Vitesse (cm/s)			Accélération (cm/s^2)			Intensité
		Z	H1	H2	Z	H1	H2	Observée
WIBRIN	115	.17	-	-	1.0	-	-	V
HUMAIN	117	.11	.15	.16	1.1	1.8	2.2	IV
VIANDEN	140	.44	.46	.50	2.2	4.4	5.5	IV
LESSINES	157	.05	.05	.09	0.5	0.9	0.9	IV
BOUGNIES	167	.03	-	-	1.1	-	-	IV
WALFERDANGE	169	.17	.26	.34	0.7	0.7	1.1	IV

A fault-plane solution (figure 4) was determined with the P-wave first motion informations from the stations in Belgium and Grand-Duchy of Luxemburg.
The mechanism is a pure dip-slip faulting for which one of the nodal planes with a strike of 130° and a dip of 70° to the southwest could correspond to the Peelrandbreuk (figure 2). The study of the aftershocks will give precise informations about this hypothesis.

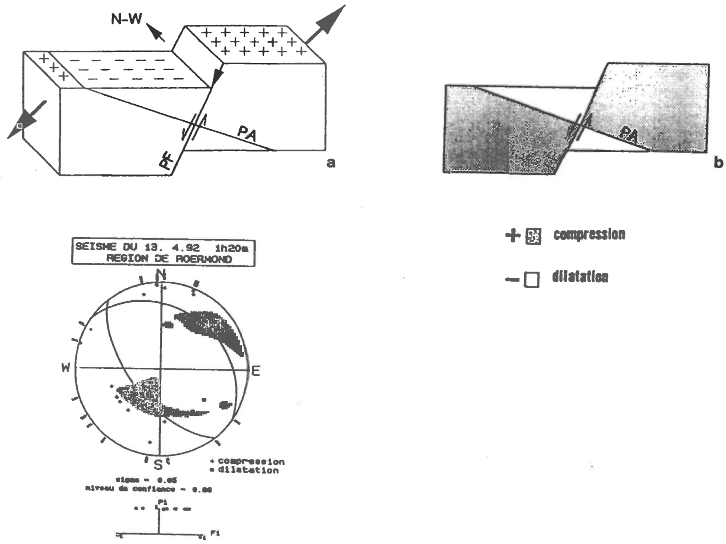

Figure 4. Fault-plane solution for the mainshock using only the data from the stations in Belgium and Grand-Duchy of Luxemburg.

SEISMICITY OF THE EUROPEAN AREA

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INTRODUCTION

In the European-Mediterranean area all types of seismotectonic units are present, from major faults marking the collision of the Eurasian and African plates to stable shields. These conditions create a challenging seismological environment which, when coupled with a high population density, huge concentration of industry and a rapid development trends, introduce many problems of pure and applied science. Thus, the study of European-Mediterranean seismicity was one of the priority tasks of ESC since the first years of its existence.
In connection with these efforts it was possible to compile a standardized earthquake catalogue for 1901-1955 which has been recently extended to 1985. The catalogue contains 13,327 shallow events and 566 events deeper than normal ($h \geq 60$ km) of $M>4$ or $I_o \geq$ VI. It is consistent in terms of magnitude determination. For all shallow events M_S was determined in a standard way, m_B for $h \geq 60$ km. Other earthquake parameters have been taken over from national or international summaries.

EPICENTRE MAPS

A homogeneous epicentre map of the European area can be constructed only for events of M(or m)>5 if the whole interval 1901-1985 is considered. The epicentre maps for M(m)<5 have been also compiled, however, they are incomplete in oceanic provinces. Earthquake regions are identified by clusters or alignments of epicentres. The principal, most active regions follow the boundary between the African and Eurasian plates, however, the earthquake pattern indicates a very complicated geometry of the collision with local subduction or fracturing and of a very variable activity along the boundary.

N(M) RELATIONSHIP

Only for 75 from the total of 137 earthquake regions sufficient data were available for cumulative $N_c(M)$ plots. The resulting $(\log N_c, M)$ distributions differ in shape and most of them differ differ from linearity in the range of large magnitudes. Most distributions correspond to the characteristic earthquake model generated by a single fault, the log-linear segments correspond o aftershocks and background seismicity of the fault and of the adjacent faultlets. The log-linear $N_c(M)$ distributions within the full magnitude range may be the result of the combination of seismicity of several faults of different dimensions in one region.

TIME DISTRIBUTION OF EARTHQUAKE ACTIVITY

The $M_s(t)$ graph for the Mediterranean area shows a relatively stable pattern of seismicity with time, however, $m_B(t)$, valid for shocks deeper than normal, indicates a steady decrease of activity after the sudden release of large amounts of seismic energy during 1926-27 in the Aegean region. A further decline of activity below h = 60 km has been observed since early sixties also in the Tyrrhenian subduction zone.

EARTHQUAKE SEQUENCES

$M_s(t)$ or $\Sigma E^{1/2}(t)$ diagrams demonstrate that the main shock with aftershocks is the most common type of an earthquake sequence, although the number of aftershocks is widely variable for events of comparable M_s, ranging from one aftershock of $M>4^1/_2$ to several dozens. Foreshocks occur rarely and their number is very low. Two main shocks of comparable M_s occur relatively frequently but not systematically in some regions. The differences $M = M - M_1$ (M_1- magnitude of the largest aftershock) range from 0.3 to 2.0, the maximum of the $M - M_1$ distribution is at 1.0. Although the foci of the sequences with $M_{max}>6^1/_2$ are often very close or almost identical in many regions the time pattern of activity repeats only very rarely.

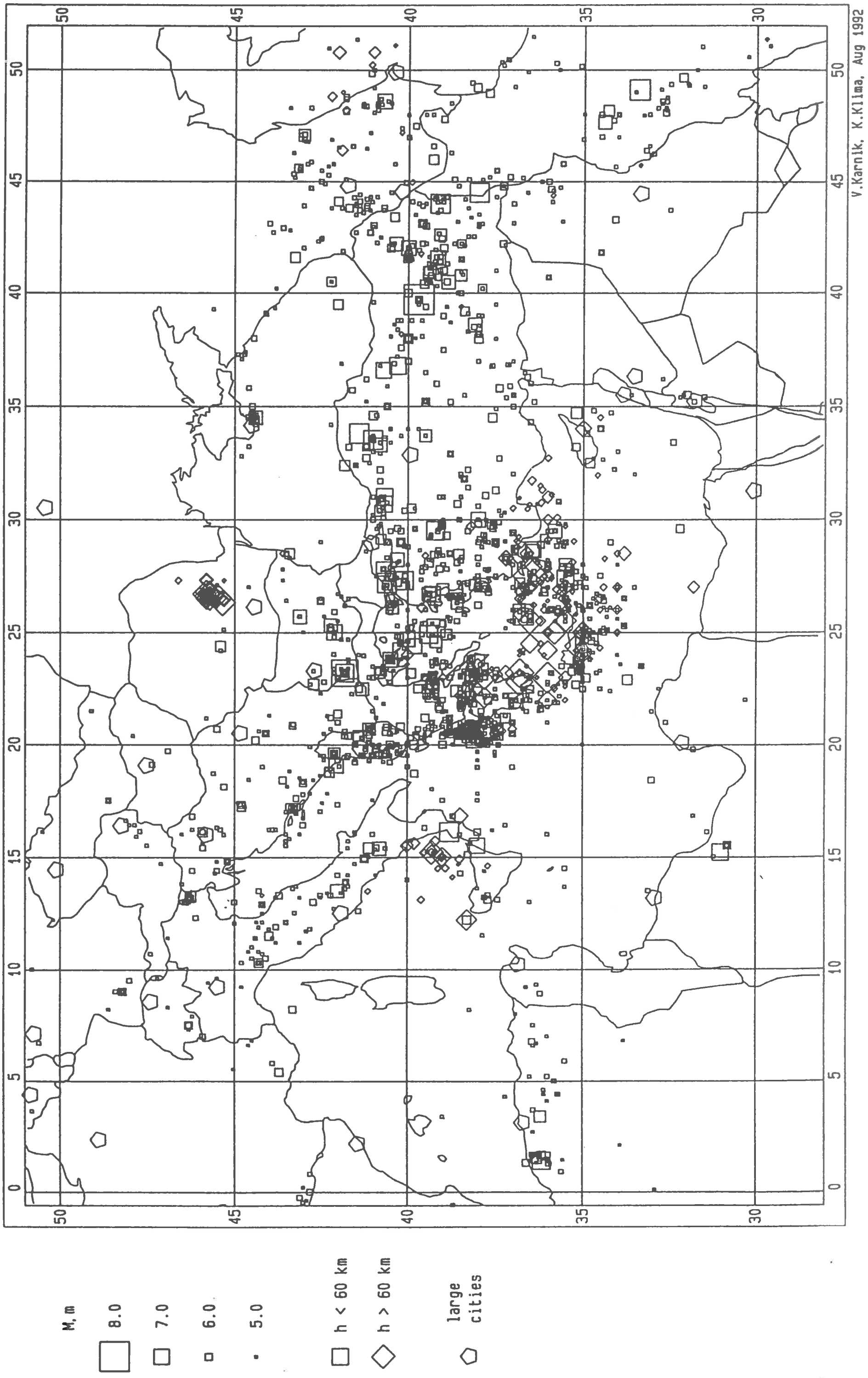
PRECURSORY PHENOMENA

The analyses of the European-Mediterranean seismicity give little hope for short or long term predictions of occurrence of large potentially damaging or destructive earthquakes. Observed phenomena, which could be identified as precursory, are rare and do not occur systematically in a certain region.

They are:
- a) quiescence periods preceding large events,
- b) unusual decay in aftershocks of the preceding large event,
- c) swarms of small and medium size earthquakes, several years before large events, followed by a quiescence period,
- d) migration from one region to the neighbouring one, some kind of alternation of activity,
- e) variation of $M=M-M_1$,
- f) certain regularity in alternation of active and quiet periods.

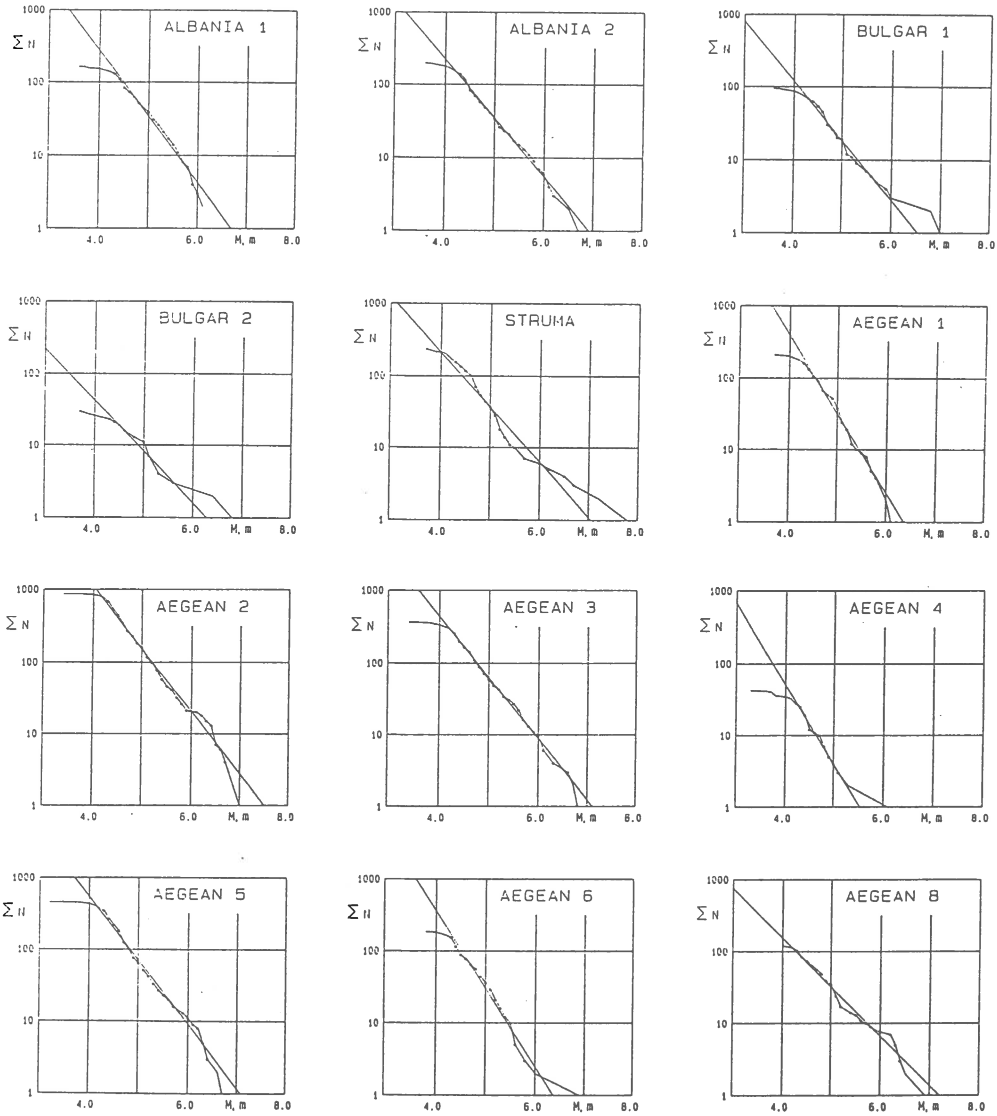
N.B. The major part of the text is a summary of two papers by V. Kárník, K. Klíma accept for press in Natural Hazards (Epicentre maps of the Mediterranean area, 1901-1985) and Tectonophysics (Magnitude-frequency distribution in the European- Mediterranean earthquake regions) in 1992.

Example



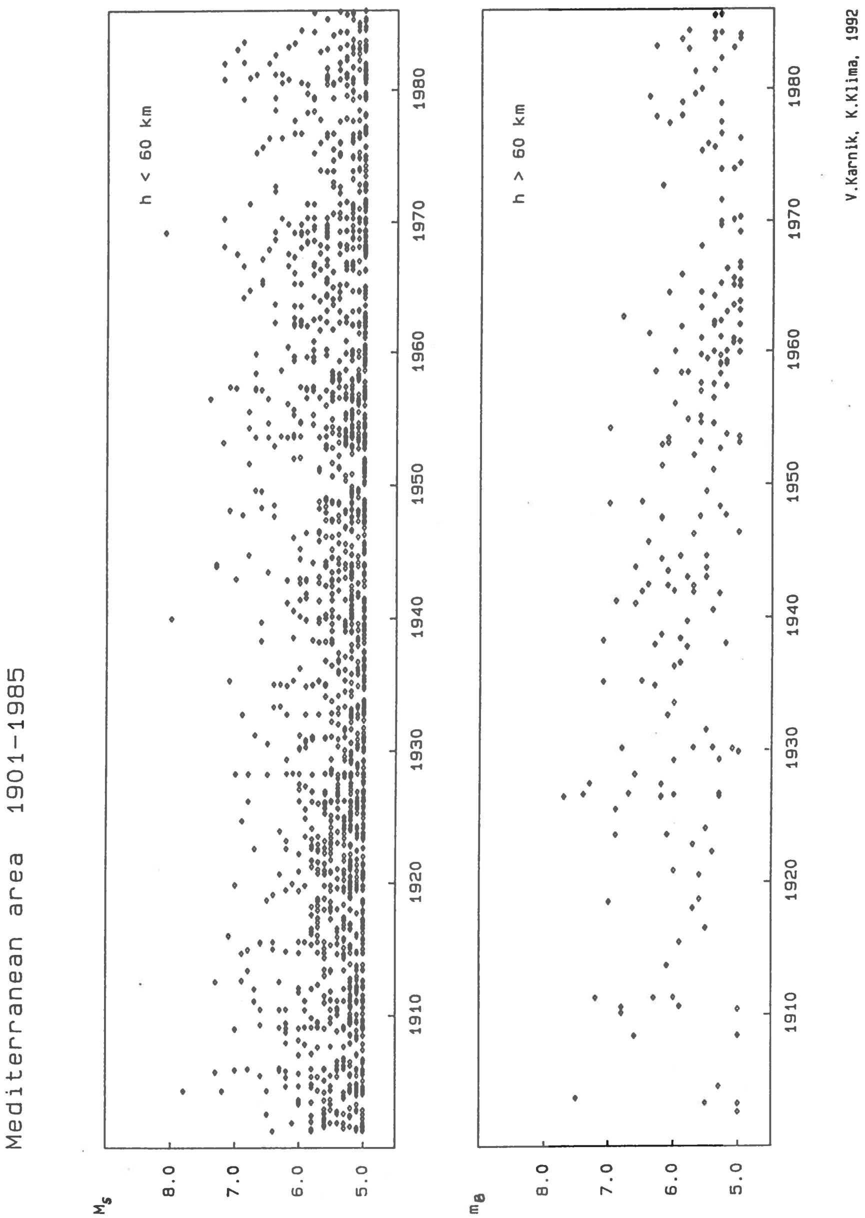
Earthquake epicentres 1901 - 1985 (M_S, $m_b \geq 5$)

Example



KARNIK, KLIMA 1992

Example



Mediterranean area 1901-1985
h < 60 km
h > 60 km
M_S
m_B
8.0
7.0
6.0
5.0
1910
1920
1930
1940
1950
1960
1970
1980
V.Karnik, K.Klima, 1992

SEISMIC ACTIVITY AND STRUCTURES IN KRESNA ZONE (SW BULGARIA) DURING THE PERIOD 1985-1989

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INTRODUCTION

The investigated zone (the so-called Kresna zone) is situated in the Balkan peninsula (φ = 40.8 - 42.3 N; λ = 21.9 - 24.1 E). It includes the famous Kresna source in SW Bulgaria and adjacent Greek and Macedonian border regions. This zone is a part of the NW margin of Thraco-Anatolian plate and is characterized by very complicated tectonics. The present work is a continuation of a few previous ones [1,2,3] devoted to the Kresna source.

DATA

The study is carried out on the basis of data about 1386 earthquakes that have occurred during the period 1985-1989. Their hypocenter parameters are estimated on the PC with the modification of HYPOLOC program [4] and the following velocity model (5):

Depth to the upper boundary of layer (km)	Vp (km/s)	Vs (km/s)
0	5.90	3.44
30	6.70	3.90
50	8.00	4.52

The data from the regional seismic network bulletins of Bulgaria, Greece and Macedonia are used.The available data are with a good azimuthal seismic station coverage. The mean errors in the hypocenter parameters determinations are: Δt = 0.45 s (for origin time); $\Delta\varphi$ = 2.3 km/s and $\Delta\lambda$ = 2.2.km/s (for the epicenter location); Δh = 8.0 km (for the depth); $\Delta\sigma$ = 0.44 km/s (for a standard deviation of determination). These errors are much lower than the errors of determination of the same parameters by the Jeffreys-Bullen crust model. During the period 1985-1989 the earthquakes under investigation are mainly with low magnitudes: 97% of them are up to magnitude 3.0. The strongest event is with magnitude 5.1. The average magnitude of all events is 1.8. The average depth of all events is h = 12 +/- 9 km, 80% of them being distributed in the depth interval 0 - 15 km.

SPACE DISTRIBUTION OF HYPOCENTERS

The epicenter distributions for the whole investigated period is shown in Fig.1. From this figure it is clear, that there exists clustering in 5 epicenter clusters: Cluster I - the area of Platchkovitza mountain; Cluster II - the Kresna source area; Cluster III - area of the Kresna source and Western Rhodopes; Cluster IV - south part of the Mesta valley in Greece and Cluster V - Valandovo zone in Macedonia. The manifested clustering is more evident on the earthquake density distribution (Fig.2). On this distribution each of the outlined clusters is characterized by a maximum of earthquake density.

It is made an attempt to clarify the seismic structures, which correspond to each cluster. It was found that the earthquakes are the deepest in Cluster I, where hypocenter depths reach 40 km, earthquakes are the shallowest in Cluster V - there the depths do not exceed 26 km. There some variations in the average magnitude in different clusters: from 1.6 in Cluster II to 2.1 in Cluster IV. The maximum observed events in each cluster are with the following magnitudes: 4.6 in Cluster I, 4.2 in Cluster II, 3.4 in Cluster III, 5.1 in Cluster IV, 3.1 in Cluster V.

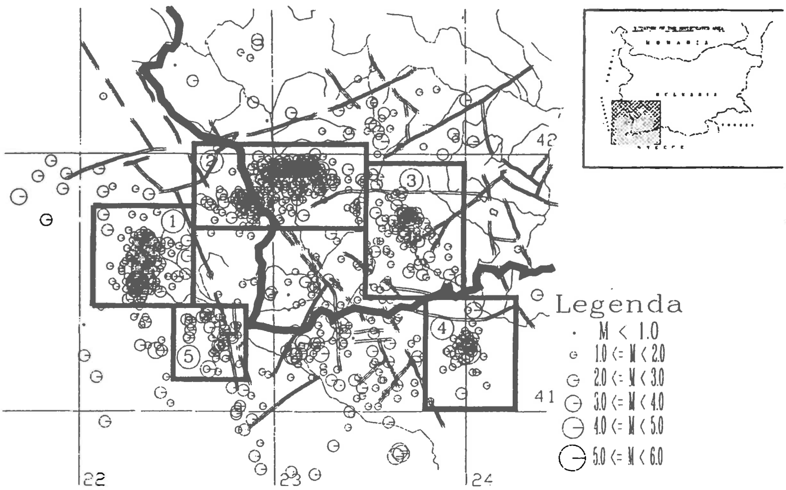

Fig.1 Epicenter locations of all recorded earthquake 1985-1989

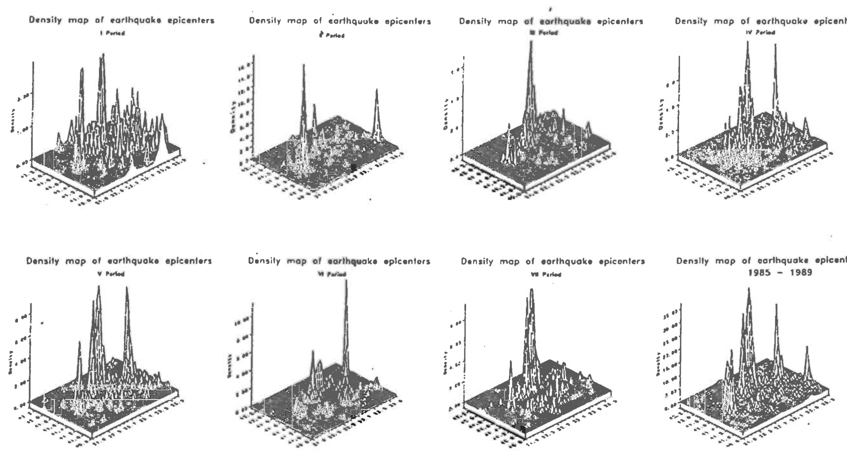

Fig.2 Density maps of earthquake epicenters per periods and for all events

TIME EVOLUTION OF THE SEISMIC ACTIVITY

The whole investigated period was divided into 7 periods according to the earthquake frequency per 15 days (Fig.3).The epicentral maps of the investigated zone for each of these periods showed a migration of earthquake activity in west-east direction. More clearly this migration is evident on the epicenter density maps for each of the seven periods (Fig.2). These maps demonstrate an existence of the inner interaction of the seismic structures in the Kresna zone. During the II and III periods a migration from Clusters I to II is observed, during the IV period the migration is from Clusters II to III and during the V period - backward to Cluster I.

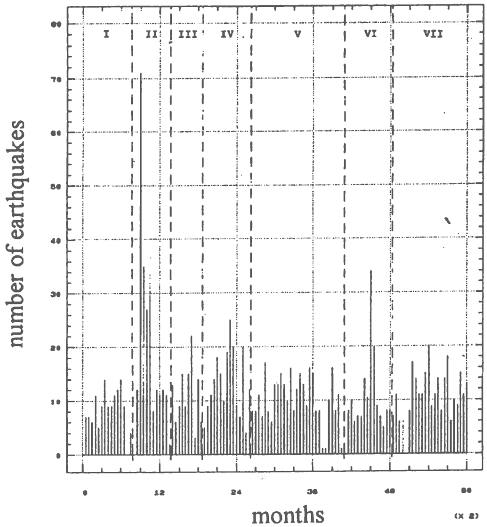

Fig.3. Number of earthquakes per 15 days

FAULT-PLANE SOLUTIONS AND TECTONIC STRESSES

For the whole investigated period the fault-plane solutions of 35 earthquakes with magnitudes between 2.8 and 5.1 were determined. These solutions were obtained by means of a PC program (6) on the basis of the first onsets of P-waves, whose quality varies from 7 to 72. The quantity of the 30% of solutions is satisfactory, but for 10% is poor., i.e. there are too many different variants of solutions. The type of faulting of these earthquakes is different: 15 solutions are of normal type, 11 of them are of reverse type, 3 of them - of dip-slip type and 6 of them - of strike-slip type (Fig.4).

In each area there are solutions of almost all types of faulting, but for some of the areas there are prevailing types. In the I area the strongest earthquake (M=4.6) is of a normal type with a fault plane along NE-SW direction. The aftershocks of this earthquake are of reverse type and there are three other events of normal type. In the second area the strongest earthquake is of normal type too, with a fault plane direction ENE-WSW. There are two events of reverse type, and three - of strike-slip type, but the prevailing type of faulting is again normal. For the third area there is not a prevailing type of faulting. Two of the events are of normal type, two of them - of strike-slip type and one - of dip-slip type. In the forth area the strongest earthquake (M=5.1) is of strike-slip type and two other ones - of normal and dip-slip types. For the fifth area there are not many fault-plane solutions (only for two events). In the central part of the investigated zone, where there are not clustering, the fault-plane solutions are of strike-slip type (3 events), reverse type (2 events) and normal type (1 event).

As a result of the summarizing the axes of tension and pressure within each of the areas the following result are obtained: almost horizontal stresses of tension with direction NW-SE in the first area, the same horizontal stresses in the second area, almost horizontal stresses in N-S direction in the forth area. The central part of the Kresna zone is characterized with intermediate stresses.

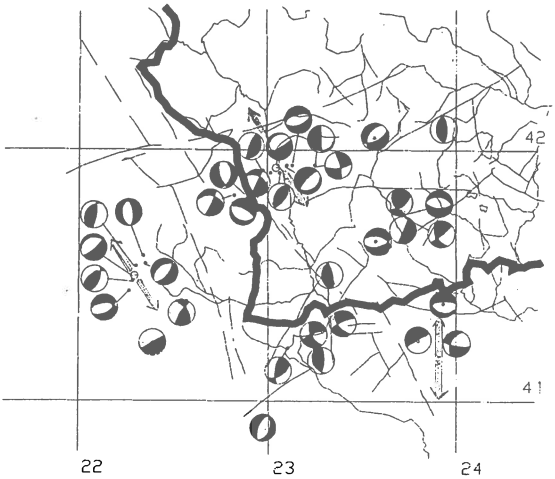

Fig.4 Fault-plane solutions of earthquakes and local tectonic stresses

CONCLUSIONS

The biggest earthquake density is observed in the southern part of the known Kresna source - area II (Fig.1) along the WSW-ENE direction. The earthquake distribution during 1985-1989 is in a good agreement with the space distribution of earthquake sequence in 1904 (main event with M=7.8). The direction of the biggest part of the nodal planes in this zone coincides with the predominant direction of epicenter density.

For the whole period under investigation it is observed the migration of the earthquake activity from West to East and backward - to West.

The obtained results about local tectonic stresses are in a good agreement with the regional tectonic stresses for the whole zone, obtained by Ritsema (7). The fault-plane solutions of strongest earthquakes, as well as of the prevailing part of the small events are of normal end reverse types, which point out the existence of the mounting generating processes.

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ESTIMATING THE PARAMETERS OF THE GUTENBERG-RICHTER RELATION USING INSTRUMENTAL AND HISTORICAL DATA

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The Gutenberg-Richter relation (G.R.R.), relating the number of events in a given interval of magnitudes, with the central magnitude of that interval, and with the interval width itself, is an important tool in assessing the risk of earthquakes and related phenomena, and in the seismic characterization of a region.

Usually the parameters of the G.R.R. are evaluated using instrumental data available for the area under study. That procedure, is not applicable for the western part of Iberia, and adjacent oceanic region, since we have only few instrumental records of seismic events with magnitude greater than 7.5. However we can use historical reports relating damages of large earthquakes and estimate their epicentral location and magnitude.

To extend the use of such magnitudes in the evaluation of the G.R.R. parameters would be very useful in assessing the seismic and tsunami risk, in that area. That fact has stimulated an effort to be able to use historical, as well as instrumental data.

In order to accomplish that goal all the available information about historical, as well of instrumental seismic data, has been gathered and integrated in an alphanumeric and graphical data base (Simões et al., 1991).

The use of such inhomogeneous data poses, however, some problems. The historical records are biased toward the larger magnitudes, which are, certainly, overrepresented.

In order to compensate that bias we have postulate the following two assumptions:

Assumption 1: The number n of earthquakes with magnitudes belonging to a given magnitude interval, occurring in a given time interval Δt, is a random variable with a Poisson distribution, i.e., with a density of probability given by:

$$\frac{e^{-\nu \Delta t} (\nu \Delta t)^n}{n!} \qquad (1)$$

where ν is the mean number of earthquakes of such magnitudes, per unit of time.

Assumption 2: For each relatively homogeneous area, and for each magnitude, exists a function, we have called "Historical Sensibility Function" (*HSF*), *HSF*(m) representing, for each magnitude m, the first date of an event of the given magnitude could have been recorded. For example, expressing *HSF* in "A.D. years", $HSF(5) = 1300$, means that the historical data can only show events of magnitude 5 if they occur after the year 1300 A.D.

Those assumptions are, of course, a simplification of reality.

The assumption 1 is certainly not true for foreshocks and aftershocks and during earthquake swarms, but it is usually assumed that it is a good approximation for large time intervals.

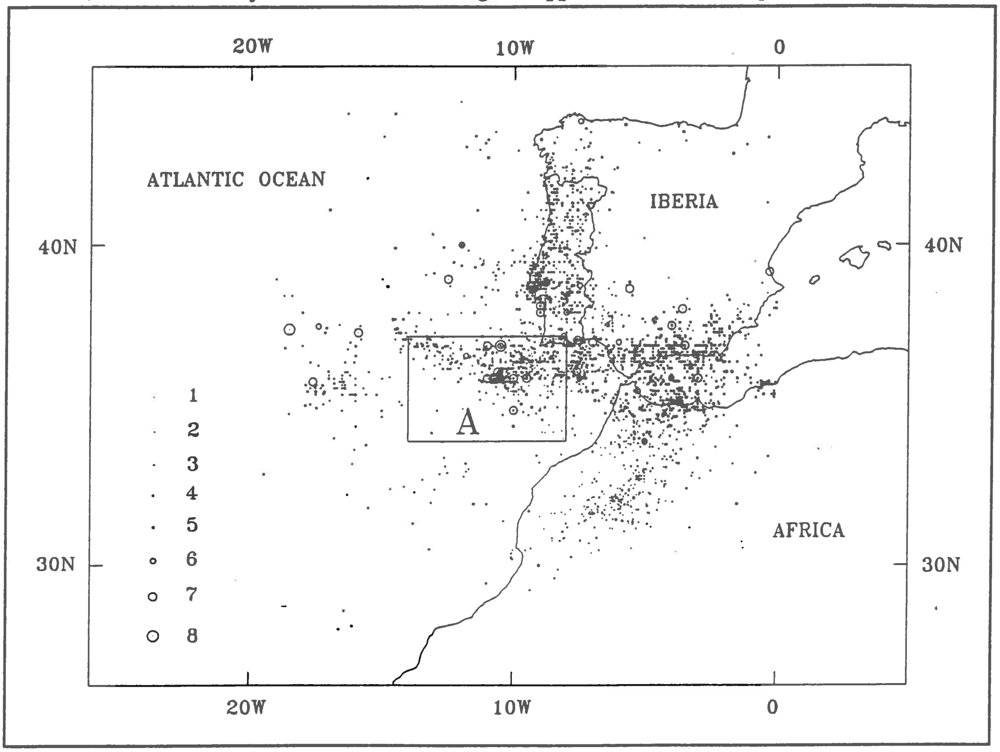

Figure 1 *The events in the seismic data base.*

Assumption 2 states that no seismic event, in an homogeneous area, of magnitude m can be recorded before *HSF*(m), and that all of those events will be recorded, if occurring, after that date. Reality is certainly more gradual, but taking this into account it will increase the complexity of the model, so, we have used the simplest, although less realistic, model.

For estimating *HSF*(m), for a given region, we have selected, from our data base, and from the events with epicenter in the region, those ones with the property that no prior event with the same, or smaller magnitude, and epicenter in the region, exists in the data base.

Considering those selected events ordered chronologically, we will call m_i the magnitude of the i^{th} of such events. In order to simplify the notation we note, symbolically, $m_0 = \infty$. It is easy to show that $m_i < m_{i-1}$, for $i = 1,\dots,n$, being n the number of chosen events.

We also assume that $HSF(m)$ is constant in each of the magnitude intervals I_i defined as $[\ m_i, m_{i-1}\ [$, for $i = 1, \dots, n$, i.e., $HSF(m) = constant = H_i$, if m belongs to I_i. Doing that we are giving to HSF the structure of a step function.

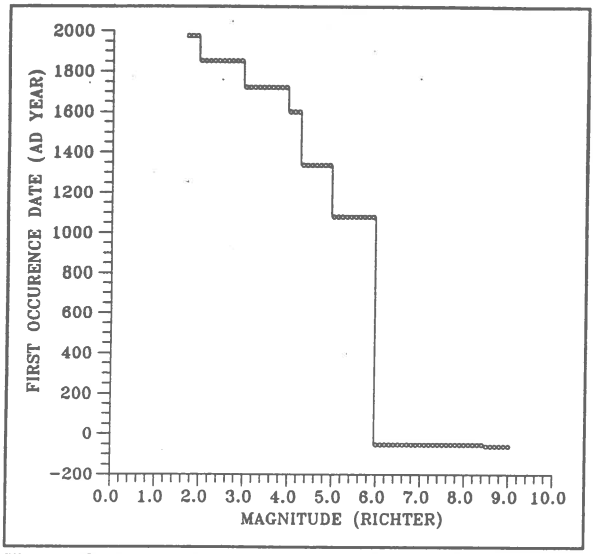

Figure 2 *An estimate of the historical sensibility function (HSF).*

What is, in that case, the density of probability that the first recorded event, with magnitude in I_i, occur in time $H_i + t$?

It can be shown, from the assumption 1, that the random variable t has a density function given by the exponential law (2):

$$f(t) = \nu e^{-\nu t},\ t \geq 0 \tag{2}$$

for $t \geq 0$, being ν the number of events with magnitude in I_i, per unit of time, quantity that is not known at this point.

For $t < 0$ the density function is nil, since no events, with such magnitude could have been recorded before H_i because of the assumption 2.

From (2) is easy to see that $f(t)$ has a maximum at $t = 0$, so the most likely instant for the occurrence of the first recorded event, with magnitude in I_i, is H_i. From that conclusion we have estimated H_i by the date of the first recorded event with magnitude in I_i. Doing that for all intervals I_i we could estimate $HSF(m)$ in $[\ m_n, \infty\ [$. It can be easily shown that m_n is the smaller magnitude in the data, so we managed to estimate $HSF(m)$ for all the available magnitudes.

Other estimators of H_i and $HSF(m)$ are possible, considering the size of I_i, and a first approximation, if available, of the G.R.R. parameters. We could also have used the 2^{th}, the 3^{th}, the k^{th}, time an event with magnitude in I_i has been recorded, changing the exponential distribution to the more general gamma distribution. However those refinements are, most likely, not suited to our simplified assumptions.

Knowing an estimate of *HSF*(*m*) we could correct the influence of the historical bias in the evaluation of the G.R.R. parameters. So, when calculating the number of seismic events, in a given small interval of magnitudes, by unit of time, we have divided the number of events by the effective time of recording, not considering the time before *HSF*(*m*), being *m* the mean magnitude of the interval. That corrected value allowed us to adjust the number of events, to the entire time duration of the data base. We referred to that new number of events as the "weighted number of events".

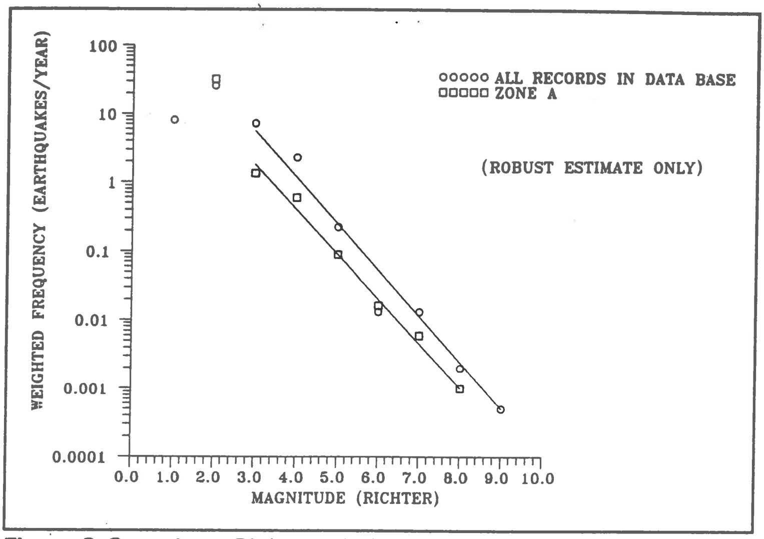

Figure 3 *Gutenberg-Richter relation for all records in data base and area "A" (see figure 1).*

We have used the "weighted number of events", instead of the measured number of events, in evaluating the G.R.R. parameters. Figure 1 shows the location of all the available epicentral location. In Figure 2 can be seen the *HSF* estimated for all the records in the data base. In Figure 3 we can see the G.R.R. for two different areas. The data in figure 3 is in good agreement with the linear relation, predicted by the G.R.R. That is an argument in favor of the assumptions we made.

An interesting conclusion is that the described methodology seems to give results in good agreement with the G.R.R., even if we consider non-homogeneous areas, for the data base we have used.

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PRESENT SEISMICITY IN NORTHERN APENNINES: SUBCRUSTAL EVENTS AND P-WAVES VELOCITY STRUCTURE

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INTRODUCTION

Northern Apennines are situated in north-western part of Italian Peninsula, between Adria Micro-plate and Tuscan Basement Micro-plate (Anderson & Jackson, 1987; Roeder, 1990).

Main features of hystorical seismicity of this region are the alignments parallel to the chain of the greatest earthquakes (Bossolasco et al., 1973). Instrumental data showed the activity of the trasverse alignments (Eva et al., 1978).

Two important question are the reliability of subcrustal events location and the seismicity of apenninic roots (Cattaneo et al., 1986; Amato and Alessandrini, 1990; Meloni et al., 1990; Suhadolc et al., 1990).

P-velocity structure is relatively well known by seismic refraction and reflection data. This is complicated by the contemporary presence, in a little space, of two basement and two Moho discontinuity, so as revealed by P-velocity inversions (Morelli et al., 1977; Buness & Giese, 1990; Scarascia and Maistrello, 1990).

Seimotectonic regional framework is dominated by strike-slip displacements (Eva et al., 1990), but a certain percentage of earthquakes react to local stresses.

These notices have been compared with the risults obtained by a temporary network, with particular care to relations of earthquakes focal depth with P-velocity structure and seismic waves attenuation.

PRESENT SEISMICITY: FOCAL DEPTH AND FAULT PLANE SOLUTIONS

A survey of seismic activity of Northern Apennines, carried out in the period August 1989-December 1990, by a temporary seismic network of seven stations, allowed to collect and process signals of local earthquakes in a magnitude range of 1.0-3.8 (Fig.1).

The most important events took place on the Po Plain side of the chain (magnitude: 3.8), but generally this area is actually interested by a low energy seismic activity. Some earthquakes epicenters are located close to Taro Line, a seismotectonic element trasverse to the chain (dashed line in figure). The Apuane metamorphic massive (A in figure) seems to be an aseismic block whereas a certain activity is related to the front of the buried chain (line with arrows in figure, redrawn from Castellarin et al., 1985).

In this work our attention was particularly dedicated to some events (11) located at depth below Ligurian Moho (H>30km). The reliability of depth parameter of these earthquakes has been controled. This review has been extended to the entire 86-91 period (12 events selected from Genoa network bulletin). Every event has been relocated 15 times, by Hypoellipse computing procedure (Lahr, 1979), varying three input parameters: velocity model, number of stations and distance weighting. Nine events has been considered reliable because depth (H) was greater than 30km in every relocation. The distribution of earthquakes with depth in this period after the revision shows that seismic activity is located in the shallow 20km of crust; a seismic gap is located in the 30-40km depth range and an increase of activity below 50km is verified.

Fault mechanisms show a good fit of event depth with an increase of the compressional character (Fig.2). Moreover a normal fault solution (H=5km, in figure) is in agreement with normal faults of Magra zone; a shallow event near to La Spezia coast (H=10km) seems to be produced by a trascurrent fault with normal component; instead, near to the watershed (H=12km) and for the deepest event (H=70km) prevail the thrust component.

P-VELOCITY AND ATTENUATION

To an investigation of crustal structure in this region, a computing procedure for the inversion of 3D-velocity model (Thurber, 1983) has been preliminarily applied. A group of 60 events have been chosen with 'Hypo' horizontal error <2km, vertical error <3km, RMS<0.5s and at least 10 observations.

Some significant relative variations have been obtained starting from a mean crustal model of 5.9km/s, in 3 layers: 0, 5 and 10km. Grid points have been spaced 10km; in the external side 20km. In the 0km layer (Fig.3) there are three high velocity zones: the most important is correlated with the Apuane metamorphic massive; the other ones are in agreement with large outcrops of sandstones (Macigno in northern border of Tuscan units and Ranzano). Low velocity zones have such relation with Flysch of Ligurian Units and recent deposits of Tuscan Units. A profile SW-NE shows that, under the Apuane high velocity zone, exist an inversion zone.

To obtain further informations about deep structure, the parameter Q_c has been studied. Seismic waves attenuation, revealed from coda-Q analysis, risult similar to Western Alps. At the frequency of 8Hz Q_c is 400.

To study the variation of this parameter with depth, we applyed the method of Del Pezzo and De Martino (1990), using better Q_c values derived by the most reliables spectral analyses. The curve that describes this dependence show a change in deep at 40km.

DISCUSSION

The comparison between vertical variation of Q_c and P Waves velocity structure, deduced from Buness & Giese (1990), shows an interesting correlation . And so also the location of the deepest earthquakes have such relation with this velocity model. Infact subcrustal events are located close Po Plain Moho discontinuity; this fact also arises comparing (see Fig.4) this work results with the reflection model of Scarascia and Maistrello (1990). This comparison also shows that Ligurian Moho is the lower boundary of the shallow seismicity. Moreover the one fault solution of a deep event shows compressive character.

A possible interpretation of these risults is that a low energy subcrustal seismic activity actually interest the Adria Unit underlyng the Tuscan Basement Microplate .

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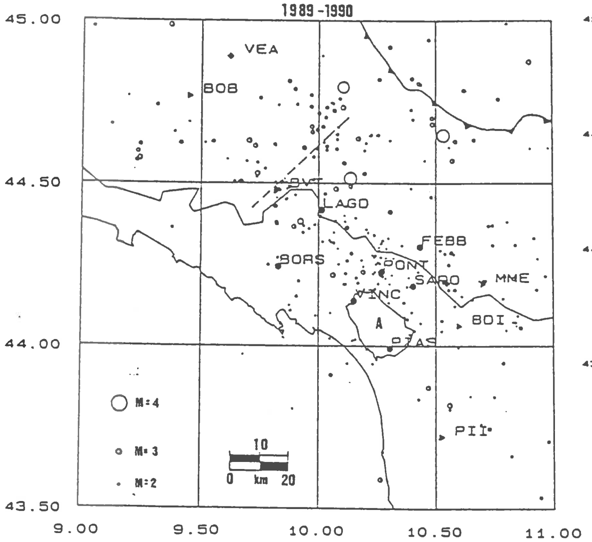

Fig. 1: Present seismicity and most important surface structures (see text for explanation).

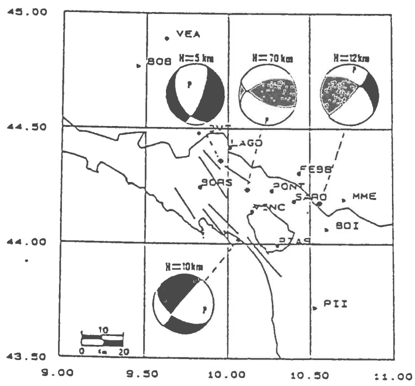

Fig. 2: Fault solutions in the period 1989-90: focuses depth and normal fault of Magra zone are indicated (straight lines).

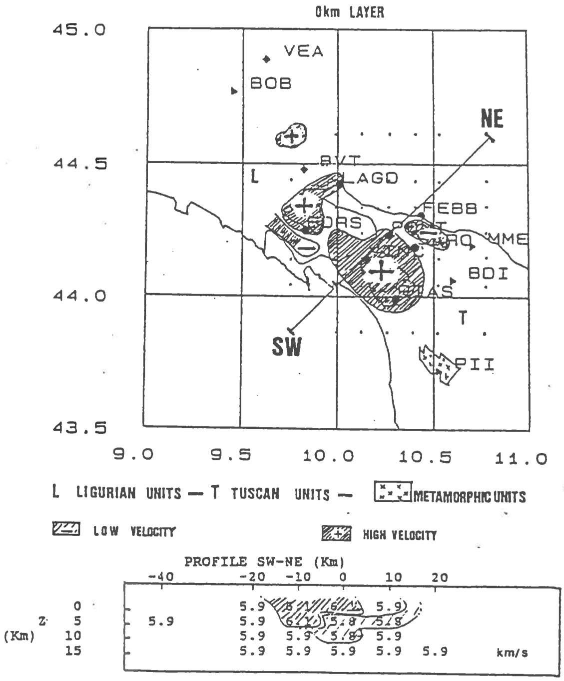

Fig. 3: 0km layer velocity structure and velocity profile SW-NE.

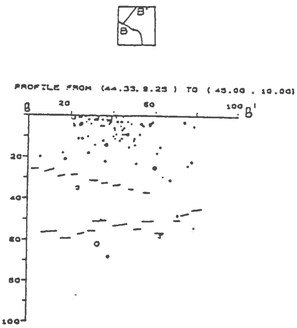

Fig. 4: Seismic reflection structure (deduced by Scarascia and Maistrello, 1990) and seismicity.

INVESTIGATION OF COAL MINING-INDUCED SEISMICITY

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INTRODUCTION

The Ostrava-Karviná mining district is situated in a geologically complicated region characterized by the contact of two large tectonic formations, the Bohemian Massif and the Carpathians. Seismic activity induced by underground mining and observed since 1912 occurs on the background of weak natural seismic activity on the territory of northern Moravia.The epicentres of weak tectonic earthquakes are concentrated into several narrower belts. Their distribution characterizes the regional natural seismicity and concerns the Jeseníky Mountains, deep tectonic faults in the neighbourhood of Opava and the vicinity of Těšín.

The character of seismic events induced by mining activity in this area is in many respects similar to weak tectonic shocks, nevertheless is obvious that the origin of mining-induced events is very closely connected in time and space with mining activity. The seismological investigations themselves are concentrated in detail on localizing foci, evaluating the released seismic energy and statistical analyses using the created data base sets. An attention is also paid to studying the interrelations between induced seismicity and intensity of mining.

LOCAL AND REGIONAL SEISMOLOGICAL NETWORK

The local network which is now in operation includes twentyfive underground and three surface stations in which the DSLA-1 or UGA instruments have been installed. The primary data recorded by one of seismometric channels are pre-processed into a so-called seismic sentence by means of a pre-processing program. The seismic sentence contains the station code, the absolute arrival times and their relative amplitudes, the integral energy for P and S waves, the arrival time of the phase with maximum amplitude and its magnitude, the arrival times of five dynamically most pronouced wave groups with the appropriate relative amplitudes. The seismological data transmitted from individual mines into the operational centre are supplemented with additional information, e.g. blasting operations being carried out, macroscopic observations in excavated coalfaces, seismoacoustic observations etc.

The regional monitoring system consisting of 10 three component Lennartz Electronic stations has 7 surface and 3 underground stations. The seismic signals recorded at the field stations are transmitted by the PCM to the interpretation centre. Here, the time information is added to the data which are decoded and made ready for their evaluation. The basic output of the pre-processing phase is a set containing arrival times, amplitudes and periods of P and S waves which is treated by the localization program, program for determining released energy or magnitude, spectral analyses etc. All the interpreted events are stored in the appropriate data base files.

SEISMOLOGICAL OPERATIONAL CENTRE

The seismological operational centre at the ČSA Colliery carries out the comprehensive evaluation of all pre-processed data (e.g. arrival times, relative amplitudes) transmitted from individual mines to this centre via modem and telephone lines, including the arrival times observed at the sites of the regional seismic polygon. The input data are processed by means of program modules for automatic localization of seismic events and determining the amount of seismic energy released in the focus.

After comprehensive processing and verification, the resultant data are stored in the seismological data base which is used for construction of the location plots for particular tectonic blocks and areas of interest, and for computing the Benioff´s graphs. The results of complex evaluation in the operational centre are then transmitted back to the geophysical laboratories of individual mines for further detailed interpretation within the frame of geomechanical service.

LONG-TERM OBSERVATIONS OF INDUCED SEISMICITY

Spatial distribution of the foci

In the contrary to the earthquake foci distribution, which are tied with tectonic faults, the analysis of distribution of the foci of induced seismic events proved that the man-made foci are mainly concentrated to the areas influenced by underground mining, i.e. areas which were mined out or being mined at present. Only in some cases the foci were located in the belts along significant tectonic faults and therefore their origin could be connected with slight tectonic movements caused by instability of rock mass due to the mining. For the correct interpretation of the location plots of induced seismic events, the mutual comparison of these plots with the contemporary mining activities is necessary (see Fig.1).

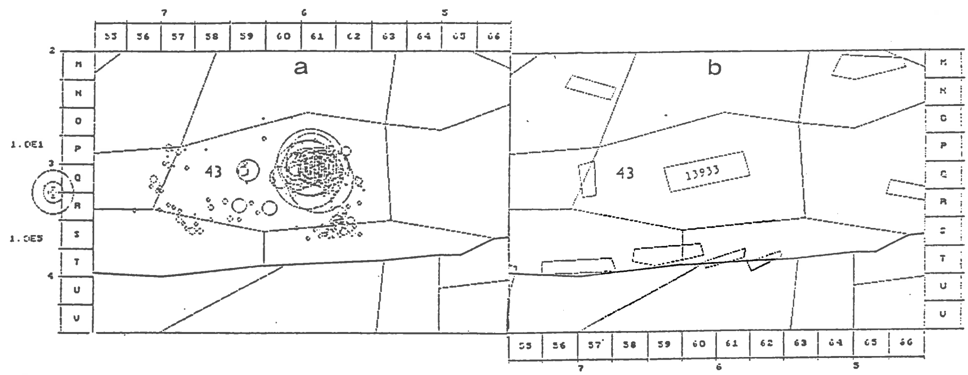

Fig.1. Detailed location plots of seismic events recorded in the 3rd tectonic block (region 43) at the ČSA Colliery and its close neighbourhood during March 1991 (**a**); contours of coalfaces mined at the same time (**b**).

Time distribution of the foci

Besides the spatial distribution of seismic events foci, their time distribution provides very important complementary information concerning the seismic regime. The time course of seismic regime at the given locality of natural earthquakes, as well as the seismic regime of mining induced events in the mines is not invariable in time. For the purpose of suitable and reliable presentation of energy-time distribution, the Benioff´s graphs have been usually used. These graphs reflect the differences of the character in seismic energy radiation in time due to the changing conditions in the focal region.

Analogously as in cases of the earthquakes, some periods of quiescience in the Benioff´s graphs of mining induced events can be observed. These periods of relatively low level of seismic energy radiation have been usually find out in the graphs before the beginning of mining activity in coalface and after its stoppage. The period between the beginning of coal extraction till creation of the first roof fall can last from several weeks up to three months approximately.After the creation of the roof fall, the Benioff´s graphs have a steepish gradient and stepwise character which reflects the intensity of coal extraction, technological operations performed and geomechanical situation at present. The decrease of the Benioff´s graph gradient appears in detail due to the short-time interruption of coal extraction, (e.g. off-days, holidays or operations problems), too. Different character of Benioff´s graphs is given in Fig.2.

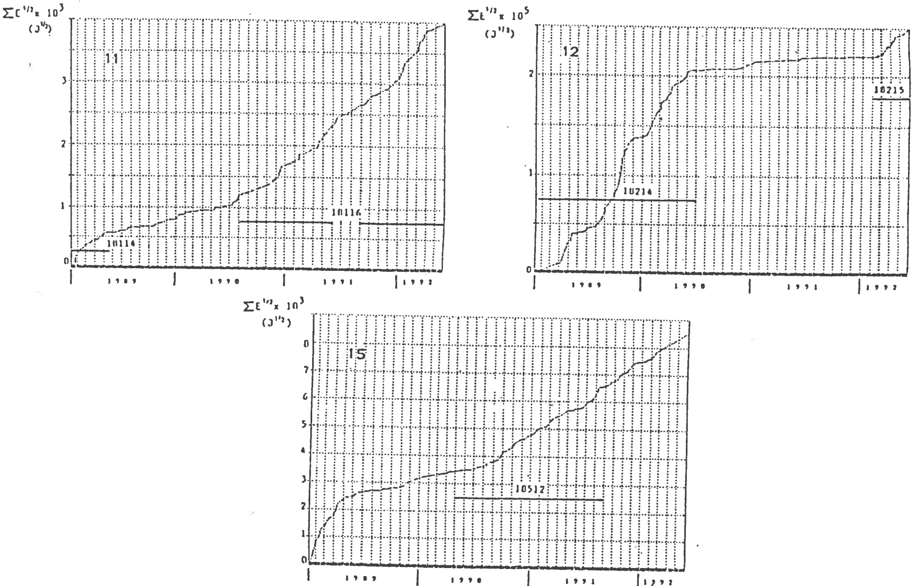

Fig.2. Benioff´s graphs for tectonic blocks Nos 11, 12 and 15 in the Dukla Colliery; the straight lines represent time scale of individual coalfaces operation.

Energy-frequency distribution

The distribution was defined according to Gutenberg-Richter frequency-magnitude relation as $\log N = a - b*\log E$, where N is the number of seismic events, E is the value of seismic energy released, a and b are numerical constants. The basic data for all statistical analyses performed were contained in operational seismological data base during the period January 1989 - May 1992. For estimation of seismic regime the b-value is characteristic. The calculations proved that the b-value for individual tectonic blocks varies within the interval of 0.49-1.12, while for the whole area under investigation the average of b-value is equal to 0.74. For all calculations only the energy classes of about $2x10^1$ J - 10^6 J were assumed. From the point of view of geomechanical practice, the tectonic blocks where higher values of the constant b were observed represent areas with lower degree of seismic risk. Three examples of energy-frequency distributions are shown in Fig.3.

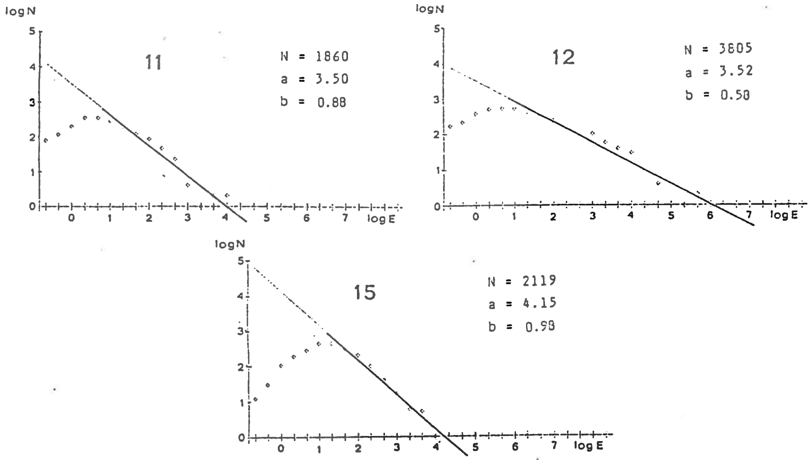

Fig.3. Energy-frequency distributions for tectonic blocks Nos 11, 12 and 15 in the Dukla Colliery during the period January 1989 - May 1992.

CONCLUSION

The operation of the local and regional seismic networks, as well as the automation of data aquisition and processing procedures contributed to the objective estimation of induced seismicity. On the basis of location plots from long-term observations, the seismically active regions were depicted. The location plots give evidence that the predominating number of seismic events have been induced by mining activity, while the insignificant number of them could originate due to slight tectonic movements along the contacts of individual tectonic blocks. For the discrimination of both types of origin, the knowledge of simultaneous mining activity in the area of interest is necessary. The origin of mining-induced events is mostly tied with flat demarcated parts of tectonic blocks, regions of multiple edges influence of the roof, boundaries of residual and safety pillars. It was also proved that the rockbursts were often observed in the areas where for several years the increased induced seismic activity had been observed.

Long-term seismic energy release was investigated using Benioff´s graphs and their diurnal increments. In both types of curves the influence of intensity of mining activity is evident. Mining-induced seismic regime was studied using the energy-frequency distributions. Analogously as in the case of differences in seismic response to mining operations, the differences in distributions were found out, too. The b-values within the interval of 0.49-1.12 were ascertained.

FOCAL MECHANISMS FROM BODY WAVEFORM INVERSION FOR SOUTHERN TURKEY

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Introduction

Southern Turkey is a region which may be represented by seismic source zones ranging from negligible activity to high levels of seismicity. Earthquakes within these zones have focal depths varying from a few kilometers to about 100 km. Errors in focal depth calculations, for example, in the area in and around Cyprus, give rise to different interpretations of seismic data (e.g., Büyükaşikoğlu, 1980; Rotstein & Kafka, 1982). Also, focal mechanism solutions based on first motions of P waves (McKenzie, 1972; Alptekin, 1973; McKenzie, 1978; Alptekin & Ezen, 1978; Jackson & McKenzie, 1984) are not necessarily always well constrained. Large differences between source parameters estimated in previous studies may lead to interpretations of the results in terms of local tectonics which differ significantly. Plotting the polarities of first motions on the lower hemisphere of the focal sphere requires the calculation of take-off angles which depend on an often unknown velocity structure in the source region. Poorly distributed stations in azimuth as well as overlooking the nature of seismograms at some stations can also give rise to misestimation of focal mechanisms. Fig. 1 shows a collection of published focal mechanisms in the study area. There are often several different solutions corresponding to the same event (e.g., Numbers 2 and 8 in western Cyprus, and numbers 1,2,6 in the far north-east of the map.

Our purpose in this study is to improve the uniform determination of focal mechanism parameters in the region and thus aid eventual interpretation in terms of local tectonics. To do this we usually prefer the use of body waveform modelling. This technique not only refines the source depth, using the surface reflections, and the traditional focal mechanism but also provides information about the source time history and indirect information about the structure, for well-recorded events.

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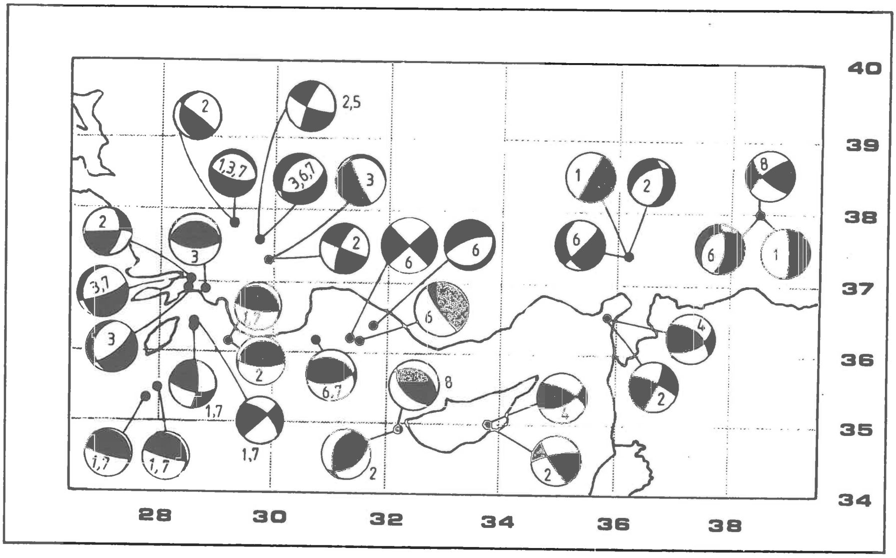

Figure 1 A compilation of fault plane solutions for some significant earthquakes in southern Turkey. Focal mechanisms estimated or given by 1) McKenzie (1972), 2) Alptekin and Ezen (1978), 3) Eyidoğan (1988), 4) Rotstein and Kafka (1982), 5) Alptekin (1973), 6) Jackson and McKenzie (1984), 7) McKenzie (1978), 8) Büyükaşikoğlu (1980).

Data and Method

The data set consists of long and short period seismograms recorded at the World Wide Standard Seismograph Network (WWSSN) stations for events (with magnitude $m_b \geq 5.0$) which occurred in southern Turkey and the Eastern Mediterranean during 1965 to 1989. In addition to our readings, the Bulletins of the International Seismological Center (ISC) data were also considered to estimate focal mechanisms using the first motion of P waves in the case of small magnitude earthquakes.

We used the method of inversion of teleseismic body waveforms, as developed by Nábělek (1984) and implemented for use on microcomputers by McCaffrey & Abers (1988), for earthquakes generating well recorded data at teleseismic distances. The method of first motion of P-waves was still adopted for earthquakes small in magnitude.

The method of inversion fits a double-couple type source mechanism, source time function, centroid depth and seismic moment to an earthquake in a specified velocity structure in the source region. A two layered velocity structure can be included. Complex sources can be modelled using subevents consisting of different source parameters. A series of contiguous shocks can also be modelled by increasing the number of source time function elements. This latter technique allows representation of sources having relatively slow rupture. The theory of the method is given in detail by (Nábělek, 1984).

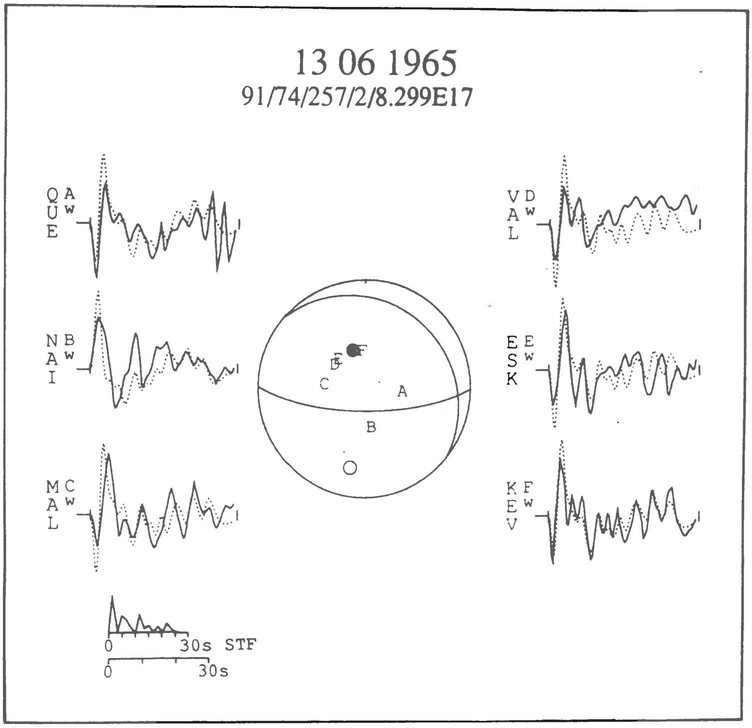

Figure 2 Waveform modelling solution for an earthquake in the eastern Menderes Graben, western Turkey. Solid lines represent observed seismograms and the synthetics calculated are shown by dotted lines. Letters in the focal sphere correspond to the positions of stations included in the analysis. The letter w is used to represent long period WWSSN data. Solid and open circles show the position of P and T axes, respectively. The header contains focal parameter information in the form strike/dip/rake/centroid depth/moment (Nm).

Results

We have examined 17 earthquakes from southern Turkey. Full details will be given by Yılmaztürk and Burton (in prep.). Some principal conclusions may be extracted and summarized here as follows:

a) The use of body waveforms significantly improves the focal mechanism solutions. For example, Fig. 2 shows the differences between published solutions (top left in Fig. 1 - reference numbers 2; 1,3,7) based on first motions of P-waves and the solution inferred from body waveforms for the earthquake of 13 June 1965. A further significant result is that this earthquake is very shallow (h=2km) as is the earthquake of August 19, 1976 (h=4km) suggesting that they are associated with the edges of the Menderes Graben. These shallow earthquakes are characterized by relatively long source time functions while source time functions of earthquakes occurring in the Antalya Bay are short in time.

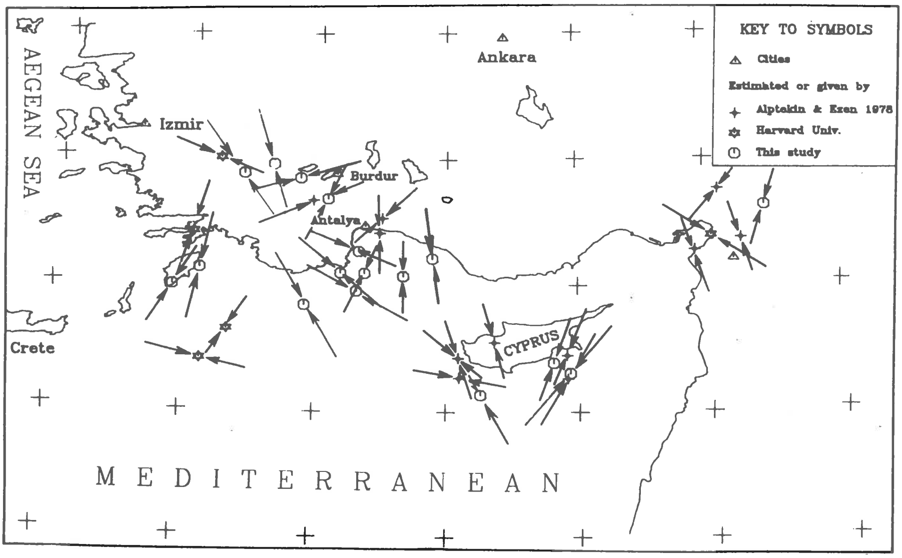

Figure 3 Distribution of P-axes for 33 earthquakes in the study area. Focal parameters of 17 earthquakes are estimated in this study. Solutions were obtained using either lower hemisphere projections, for small-magnitude events, or body waveform inversions at teleseismic distances.

b) Stress directions (Fig. 3) appear to follow the local structure in and around the Menderes Graben rather than being controlled by regional tectonic forces assumed to yield a NS extension in western Turkey(e.g., Papazachos, 1976; Eyidoğan, 1988).

c) Stresses due to a sinking slab within the Antalya Bay differ from the surrounding areas (Fig. 3).

d) Focal depths inferred from the inversion of body waveforms for events in southwestern Turkey are compatible with those reported by the ISC bulletins and previous studies. However, focal depths of earthquakes in Antalya Bay are found to be less than those reported in different catalogues.

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SEISMOGENESIS OF FENNOSCANDIA: PLATE TECTONICS OR ISOSTATIC REBOUND?

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Generally, the origin of intraplate earthquakes is poorly known. Main hypotheses about the seismicity in the Fennoscandian shield are release of stress transported from the nearest plate boundary, the North Atlantic Ridge near Iceland, and release of stress due to the postglacial isostatic rebound.

Indicators of both hypotheses are presented and discussed. They include relative size of compressional v. extensional horizontal strain, correlation of microseismicity with curvature of land uplift, major geological features (boulder caves, fault scarps, marks of landslides and liquefaction) connected to large earthquakes of late-glacial origin, differential strain along the coast of the Gulf of Bothnia, earthquake focal mechanisms, spatial distribution of b-values, and correlation of Fennoscandian and North Atlantic Ridge seismicities.

Although conclusive evidence is lacking, there are probably contributions from both proposed seismogenic mechanisms. An extended discussion is given in Wahlström (1993).

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REGIONAL VARIATIONS OF THE AFTERSHOCK ACTIVITY IN VERY ACTIVE REGIONS OF THE WORLD

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INTRODUCTION

This paper confines itself on the regional variations of the aftershock activity in the world. Such studies are useful because they can describe the geographical distribution of several physical properties (homogeneity of materials, stress distribution, etc.), as well as they provide information that is important to deduce the structure of the Earth's crust. The aftershock activity of an earthquake can be indicated by the ratio of the total energy of aftershocks (E_a) to the energy of the main shock (E_o). Utsu (1961) suggested that the difference D_1 in the magnitudes between the main shock M, and its largest aftershock M_1 can be used as a measure of the aftershock activity. In fact the M_1 value is nearly proportional to the logarithm of the total aftershocks energy (Mogi 1967, Papazachos 1971), because a linear correlation has been found between the above referred quantities. In this way the difference D_1 can be used instead of the logarithm of the ratio E_o to E_a. For this purpose a complete catalogue of earthquakes is used. The parameter which is considered to be a measure of the aftershock activity, is the difference D_1, of the magnitudes between the main shock M and the largest aftershock M_1.

THE DATA

The source of the data for this study are 182 earthquake sequences which occurred between 1964 and 1986 in the whole world with main shocks $M_s \geq 7.0$ and focal depth less than 65 Km, listed in a previous catalogue (Tsapanos 1990a). Attention is limited to shallow sequences, because intermediate and deep focus earthquakes rarely have aftershocks (Olsson 1979). In order to enrich our data, 43 earthquake sequences, which occurred in the whole Earth during the time period 1904-1963 with main shocks $M_s \geq 7.4$ and focal depth less than 65 Km (Tsapanos et al. 1988) are added to the first data set.

VARIATIONS OF THE DIFFERENCE D_1 IN SOME VERY ACTIVE REGIONS OF THE WORLD

In order to calculate the parameter D_1 for some very seismically active regions of the world, we have firstly to extract the aftershock sequences which occurred in every one of these regions from the whole file. For this purpose we used the POLYGON computer program, which estimates the earthquakes, occurring in a polygon which surrounds every examined region. The parameter D_1 was then computed for each one of the aftershock sequences which belong to a specific region, and the mean D_1 value with its uncertainty are also calculated for this region. Eleven of them (regions 1,3,4,5,-AREA 1, and regions 9,11,12,15,16,17,18-AREA 2) belong to the very active belt of the circum-Pacific and one (region 22-AREA 3) is the continent of Asia (fig. 1). The mean D_1 values and their uncertainties for the above referred regions are presented in Table (1).

Table 1. - Estimated mean values of the parameter D_1 for the examined regions. The uncertainties (UNCERT.) are also given.

	REGIONS	D_1 VALUES ± UNCERT.
	1	1.60±0.48
AREA 1	3	1.62±0.41
	4	1.66±0.22
	5	1.64±0.45
	9	1.45±0.51
	11	1.11±0.54
	12	1.12±0.53
AREA 2	15	1.38±0.60
	16	1.54±0.49
	17	1.11±0.61
	18	1.48±0.41
AREA 3	22	1.40±0.57

We can observe that the mean D_1 values of AREA 1 are in general significantly higher that the ones of AREA 2. We can also see that the D_1 values in AREA 1 are strongly concentrated between the values 1.60-1.66, while the corresponding values in AREA 2 are spread between the values 1.11-1.54. In order to check whether the two distributions of the D_1 values (between AREA 1 and AREA 2) have the same means, the T-test has been applied. For AREA 1 the mean D_1 value is 1.63±0.03 and the variance is VAR1=0.00067, while for AREA 2 and for mean D_1 value equal to 1.31±0.19 the variance is VAR2=0.03705. The results showed that the parameter T=3.2048 and the probability, that the two D_1 values distributions to have the same mean is 1%. This probability can be interpreted that the mean two D_1 values are totally different. On the other hand the mean D_1 value which is found for Asian continent is 1.40±0.57. We can see that the AREA 3 has intermediate mean D_1 values, situated between the mean D_1 values of AREAS 1 and 2.

AFTERSHOCK ACTIVITY

As we have mentioned above the aftershock activity has been measured here by the difference of magnitudes between the main shock and its largest aftershock. The D_1 values are plotted on the epicenters of the corresponding earthquakes (fig.1). Five different symbols have been used to represent five ranges of aftershock activity and qualitative terms are used in this study to denote these ranges. The terms are listed in Table (2). According to Mogi (1967) low D_1 values indicate high aftershock activity and vice versa.

Table 2. - Qualitative terms which are used to denote the five ranges of the aftershock activity.

TERM DENOTING THE SIZE OF THE AFTERSHOCK ACTIVITY	ASSOCIATED D_1 RANGES
High	$D_1 \le 0.5$
Major	$0.6 \le D_1 \le 1.0$
Strong	$1.1 \le D_1 \le 1.5$
Moderate	$1.6 \le D_1 \le 2.0$
Low	$D_1 > 2.0$

The whole world is divided in several zones of aftershock activity, covered by all the ranges.

CONCLUSIONS

Low D_1 values indicate high aftershock activity and correspond to high degree of fracturing, while high values of the parameter D_1 show low aftershock activity and refer to low degree of fracturing (Mogi 1967). High D_1 values are found for AREA 1, low values of the same parameter are estimated for AREA 2 and a value, between those of the two areas, is calculated for AREA 3. The application of the T-test disclosed that the mean D_1 values, between AREA 1 (1.63) and AREA 2 (1.31), are totally different. We refer here the D_1 value of AREA 3 which is equal to 1.40. This could mean that the mechanical behavior of the examined areas material is responsible for the difference in the D_1 values. Low aftershock activity and well defined zones of it are demonstrated in AREA 1, while in AREA 2 the aftershock activity seems to be higher than AREA 1 and well defined zones of aftershock activity are presented only in few cases. Absence of zones of aftershock activity, which can be characterized as a medium one, is obvious in AREA 3. This could be due to the difference of the degree of fracturing between AREAS 1, 2 and 3, which is depending on the tectonic characteristics of them.

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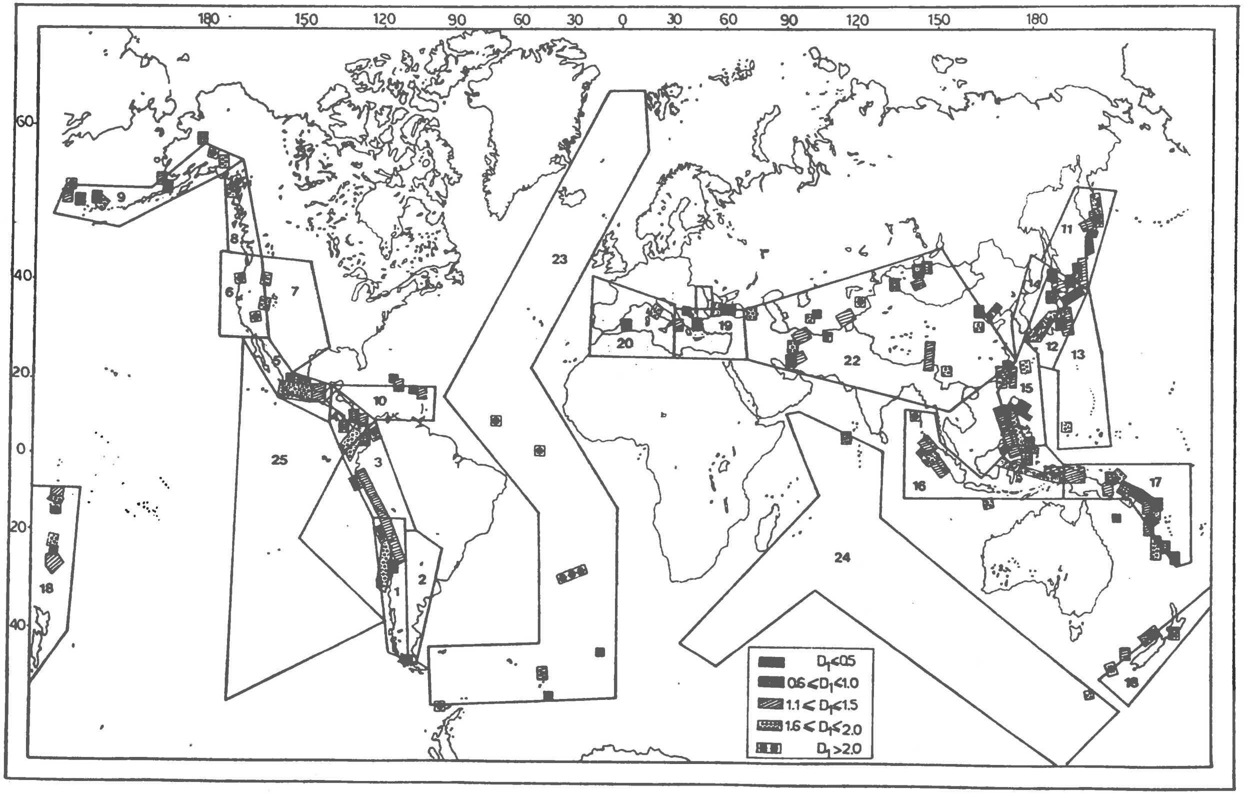

Fig.1.- Regional variations of aftershock activity in the whole world.

REGULARITIES OF THE SPATIAL ORGANIZATION OF THE BLACK SEA SEISMICITY.

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The Black Sea bassin refers to a wide seismic active belt. Active structures of this belt cross several seismic regions. The geodynamic processes, occuring in the active structures, must be reflected in seismicity. The hierarchy of geologic-geophysical and tectonic structures must generate the hierarchy in seismicity structures. Proceeding from the hypothesis of plate horisontal movements, one can suggests that the seismic situation in the Black Sea bassin is determined, mainly, by the dynamic characteristics of interaction of the Arabian and the Eurasian plates. A complex mosaic of the stress field is generated by interaction of structures of the lower class - subplates and blocks.

In this paper an attempt to show that the Black Sea bassin seismicity has a hierarchical multy-level structure, which displays in the peculiarities of the spatial arrangement of seismicity, is undertaken. The earthquake catalogues served as the initial data (Alsan 1975,Shebalin 1974,Kondorskaya & Shebalin 1982).

The spatial arrangement is noticeable in the earthquake epicenters distribution of the Black Sea bassin (Fig.1). Depending on the area of the examined regions and a magnitude threshold, the blocks of a different size are defined (Fig.2a-c).In the map of the crust earthquake epicenters with the magnitude $M \geq 5.5$ one can define some large blocks measuring 600-800 km (Fig.2a), located in the aquatoriums of the Black Sea and the Aegean Sea (blocks 1,2). In addition, two large blocks are outlined by epicenters in the Central Turkey and in the south of Bolgaria. When a scale increases and a magnitude level decreases down to $M=2.5$, the thinner structure of seismicity becomes noticeable, and one can define the contours of the blocks measuring 100-200 km (Fig.2b). A detail analysis of the seismicity field in the local areas, e.g. in the region of the southern coast of the Crimea, reveals the seismicity mosaic structure, where the contours of the blocks, measuring some tens of kilometres, are observed (Fig.2c). Thus, the seismicity field, considered on different scales,has a hierarchical structure of a block type. It is rather connected with the features of the tectonic movements in the Earth's crust of the Black Sea bassin.

Movements of the Arabian and Eurasian plates relative to each other create a complex stress field both on a joint of the plates and inside them. The irregular distribution of stresses inside the plates leads to the appearence of weakened sectors along which the rupture occurances are possible. The system of seismic lineaments on different scale levels points to the presence of such weakened traces.

A section at the depth along the diagonal profile of the Black Sea bassin has the following peculiarities (Fig.2d). At the profile edges there are sources in the uppermost mantle. In the centre of the profile the depths are located within the Earth's crust. If assume the Chechunov's hypothesis, according to which there is an uplifted layer of the asthenospheric asthenolith in the region of the Black Sea trough the depth distribution of sources along this profile becomes clear. A plastic layer of the asthenolith in the mantle doesn't allow to reliaze seismic processes of a considerable energy.

Fig.2 (e and f) shows the sections at the depth along the profiles B-B′ and C-C′. these profiles characterize the depth structure of seismicity along and across the joint boundary of the Black Sea subplate with the Eurasian plate. In the plots one can sea a tendency to the increasing of the depth of the sources in the electoral directions. For the B-B′ profile the seismofocal layer is stretching depthward to the north-east,for the C-C′ profile -to the south-east, i.e. from the Crimean coast to the deep-water trough. The cause of this tendency, probably, consists in the stratification and many-stages of the tectonics not in the deep layers only, but also in the upper parts of the Eath's crust.

A quantitative picture of the spatial distribution of seismicity has been obtained by two methods: the first one is the Morishita index; the second - a spectrum of fractal dimensions. The first method gives a possibility to estimate a type of the clustering, under the condition, that it exists, and a size of groups, if those exist, too. This method was firstly used Morishita(1959), Ouchi and Uekawa (1986), it was used Арефьев and Шебалин (1988).

A spectrum of fractal dimension is based on the calculations of the Renie function (Г.Шустер,1988). As it is known , the difference between topological and entropic dimensions shows the degree of spatial homogeneity of a set of epicenters under examination.

The next catalogue has been taken as the initial data: time- from 1900 to 1991,latitude - $35^\circ \div 50^\circ$,longitude - $20^\circ \div 52^\circ$,magnitude $\geq 4.5(M_{LH})$. For these data, the Morishita index showed, that there was the clustering on all permissible scale levels. Absence of breaks in the plot doesn't allow to separate any dominating linear size of a group of epicenters. But their clustering on all scale levels testifies to that this system of epicenters is self-similar. A question on a type of self-similarity is not considered in this paper.

There has been obtained the following spectrum of fractal dimensions for the whole cataloque: topological dimension D_0=1.713, entropic dimension D_1=1.374, correlation dimension D_2=1.003. Judge by the topological dimension D_0, one can say, that this set of epicenters has a fractal dimension of random and spatial inhomogeneity of this system of epicenters as D_0-D_1= 1.718-1.374 = 0.339, one can see, that the degree considerably differs from a similar index for uninform and random sets (D_0-D_1 make up ≈ 0.001; 0.002).

In addition, there has been made the excepts from the common catalogue (fig. 1), the energetic and time limits were the same. All three subcatalogues were investigated according to the Morishita index and a spectrum of fractal dimensions to define spatial peculiarities on a lower scale level.

The graph I_δ for the region N1 has been obtained the same as for the whole catalogue, that confirms a possibility of self-similarity on all scale levels. The graph breaks on the 200 and 500 km levels allow to say about the presence of the epicentral groups (or about the emptiness between them) of a linear size of such an order. A set of fractal dimensions is the next: D_0=1.709, D_1=1.615, D_2=1.494. The degree of spatial inhomogeneity $\delta = D_0 - D_1 = 0.094$ says about the sufficient spatial homogeneity of this region.

The Morishita index I_δ for the region N2 also gives the clustering on all scale levels. The breaks of the graph I_δ on the 60÷600 km level are connected, possibly, with the linear sizes of the North-Anatolian fault zone. The spectrum of fractal dimensions is the next for this region: D_0=1.393, D_1= 1.321, D_2= 1.313. The spatial inhomogeneity is δ=0.072.

In the graph I_δ for the region N3 the breaks are absent, though the graph itself testifies to the clustering on all scale levels the fractal dimensions made up the next set: D_0=1.569, D_1=1.494, D_2=1.412. The degree of spatial inhomogeneity was 0.070.

As a whole, one can say that the clustering of epicenters on all scale levels is observed for both the total investigated area and the regions N1-3, that allows to tell about the availability of self-similarity of the epicentral system. Besides that, the difference between fractal dimensions of the whole catalogue and three regions N1-3, and fractal dimensions of random and uniform distributions of epicenters gives a possibility to conclude, that all investigated areas are fractal and spatially inuniform.

Thus, the Black Sea bassin seismicity submits to the main natural laws of the global geodynamics and the dynamics of discrete hierarchical systems (Садовский I979, but has its own local features, which demand further investigations.

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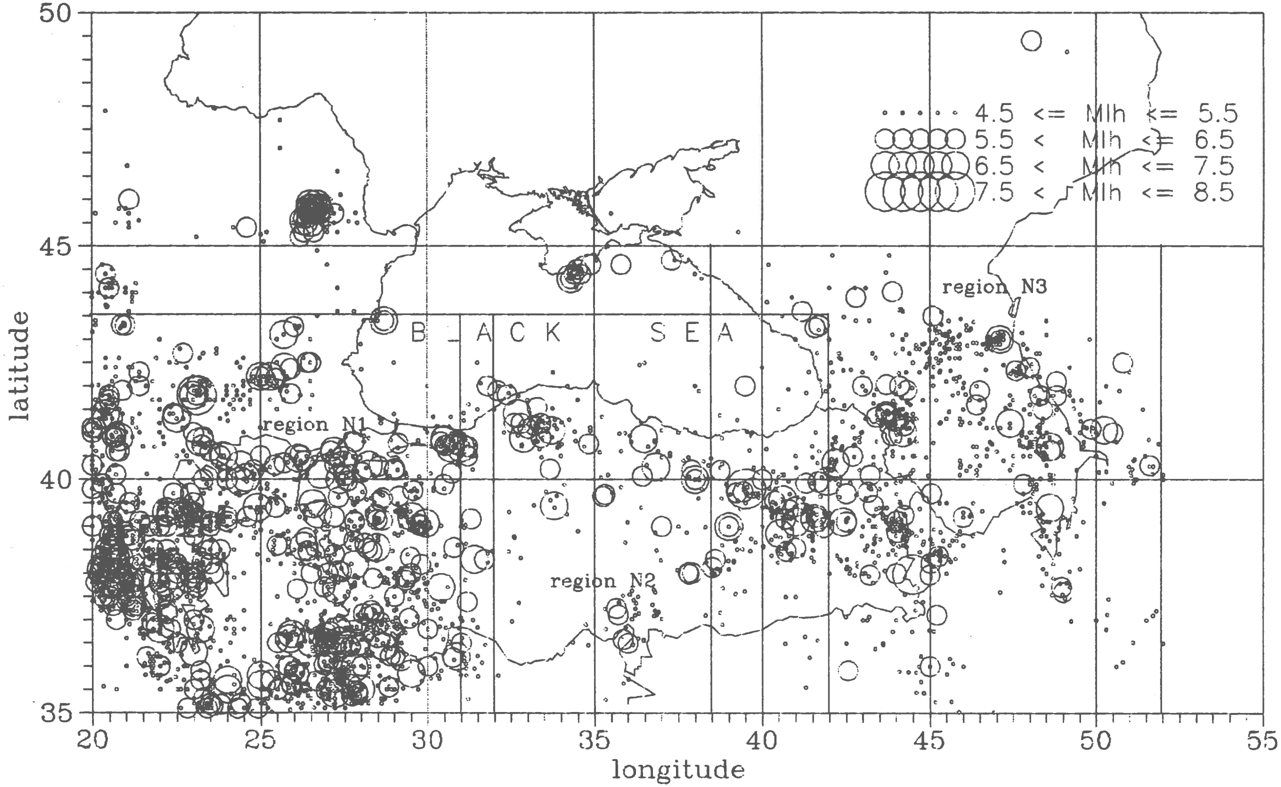


Fig 1. Scheme of the earthquake epicenters location with M 4.5 of the Black Sea bassin; 1 – 3 – areas for the calculation of the Morishita Index and a spectrum fractal dimension.

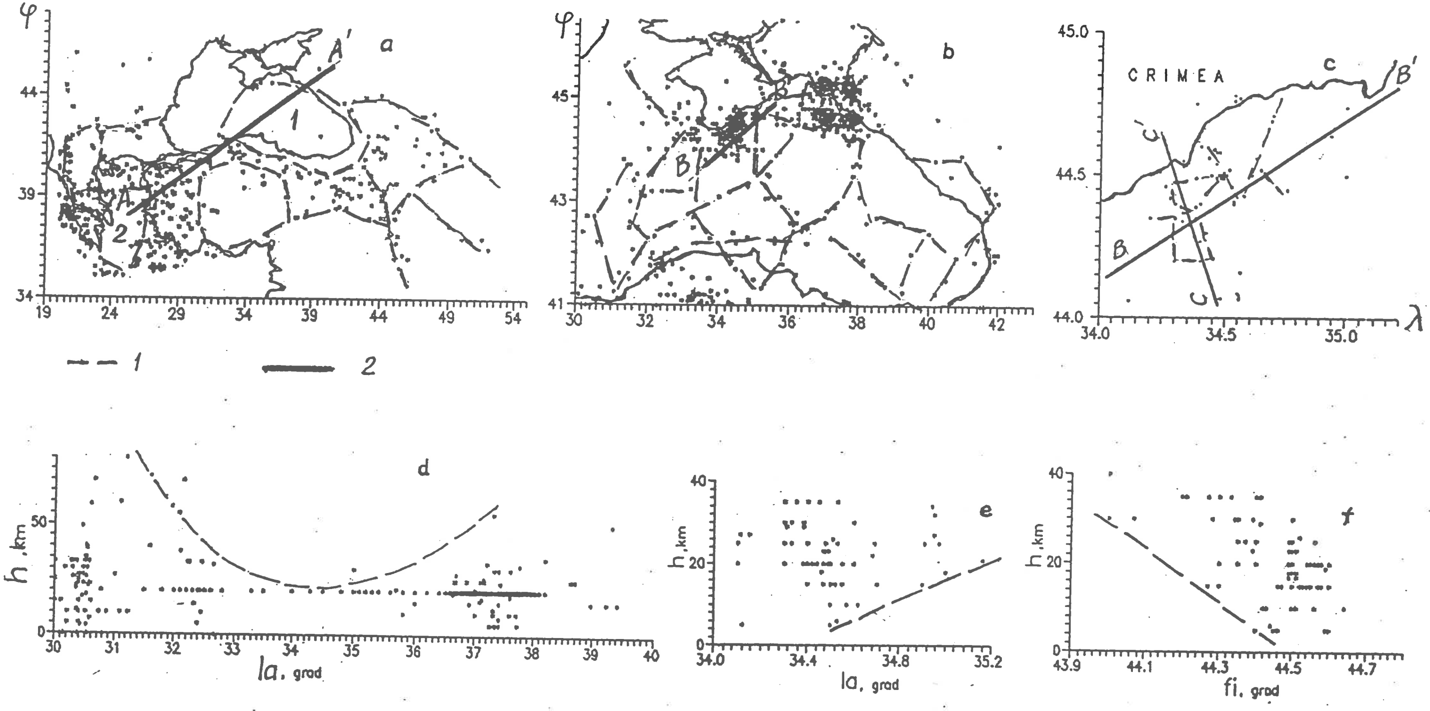
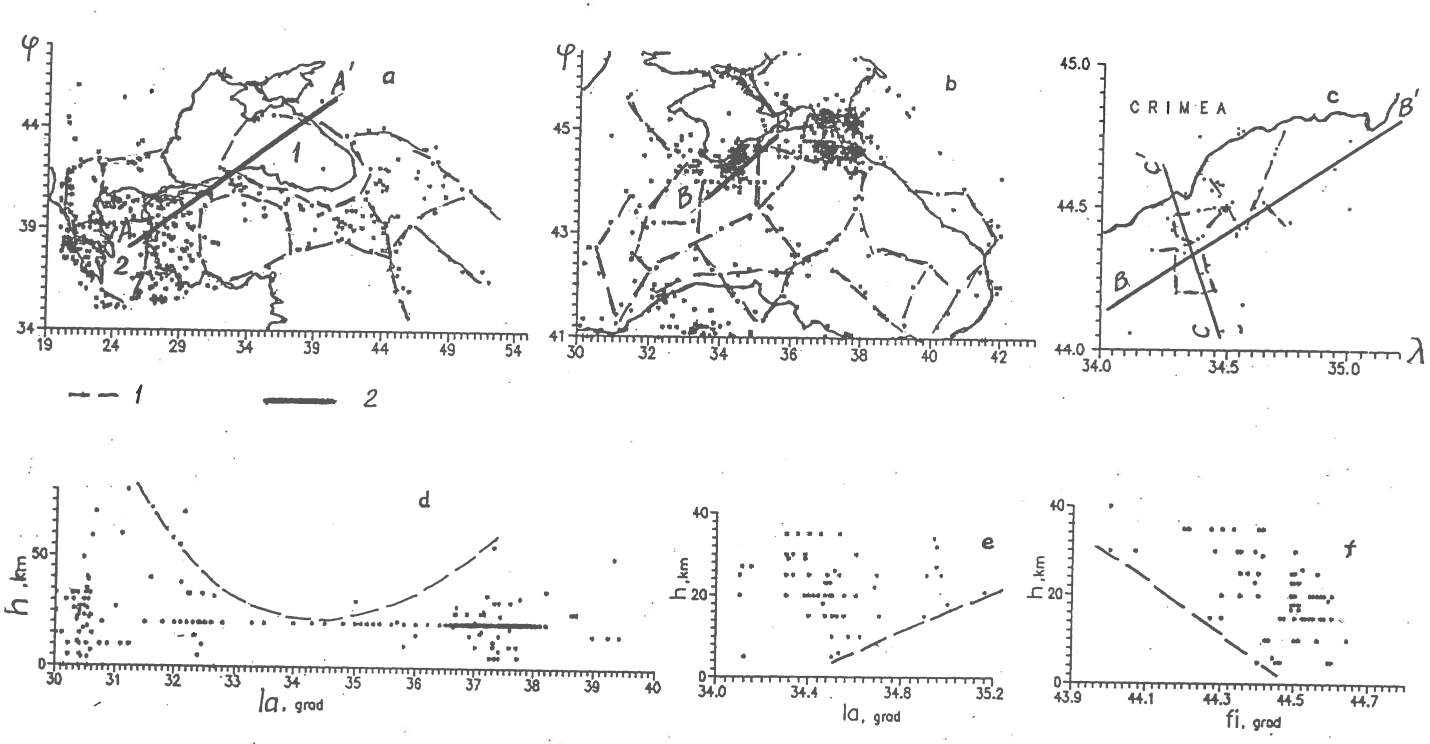


Fig.2. Scheme of the earthquakes of the Black Sea bassin of different scales and the depth sections along the profiles; a - the whole area with M≥5.5, b - the Black Sea sub-plate with M≥3.0, c - a fragment of the northern edge of the Black Sea subplate (the Crimean region) with M≥2.5. The depth distribution of sources along the profiles: AA'(d), BB' (e), CC'(f). 1- boundaries of the defined blocks, 2- profile lines of the sections.



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THE EARTHQUAKE SEQUENCE OF RIMNICU SARAT (ROMANIA) 31 AUGUST - 1 SEPTEMBER, 1991

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The Rîmnicu Sărat area, in the Vrancea zone of normal depth earthquakes, is located at the exterior of the Carpathian Arc bend. It is characterized by the occurrence of crustal events with $M_S \leq 5.0$.

A seismic sequence of about 60 earthquakes occurred during August 31 - September 1, 1991. The sequence began on August 31, with 3 foreshocks with M_L=3.8, 2.1 and 2.4, followed by the main shock (M_L=4.6). The largest aftershock occurred after about 2 hours and had a magnitude M_L=4.3. Digital waveforms recorded by 10 stations of the Romanian telemetered seismic network, equipped with short period S-13 instruments, vertical component, are analysed. 31 events with at least 8 arrivals are localized by using a JHD technique.

The seismic stations and epicentral distribution of the hypocenters are presented in Fig.1. The epicentral area can be approximated by an ellipse of around 94 km^2. The space orientation and time migration of the epicenters from SW to NE , on a direction N 32° E are emphasized (Fig.2). This result agrees well with the focal mechanism obtained by Radu and Utale (1992) for the main shock and the seismotectonics of the region (Polonic, 1986). A good correlation is also pointed out with the previous significant Rîmnicu Sărat seismic sequence of February 21-22, 1983 (Oncescu and Apolozan, 1984).

The depths are in the range 27-38km, with a predominant value around 30km. The duration - magnitude of the analysed earthqakes lies between 1.9 and 4.6.

13 events were selected for the source parameter determination. S waveform windows of 2-7 seconds were used for the Fourier analysis. The spectra were corrected by the instrument response and attenuation, by using the frequency dependent Q factor estimated from coda waves. The following source parameters were computed based on SEIS89 program (Baumbach, 1991) from the S displacement spectra for a Brune source model: seismic moment M_0, source radius r, static stress drop $\Delta\sigma$ and average dislocation u. Linear scalings of the source parameters with magnitude are given in Figs.3-6.

$$\log M_0 = (1.541\pm0.143)M_L + (14.662\pm0.511)$$
$$\log\Delta\sigma = (1.106\pm0.091)M_L - (3.635\pm0.325)$$
$$\log u = (1.039\pm0.088)M_L - (3.454\pm0.332)$$
$$\log r = (0.120\pm0.027)M_L + (2.101\pm0.096)$$

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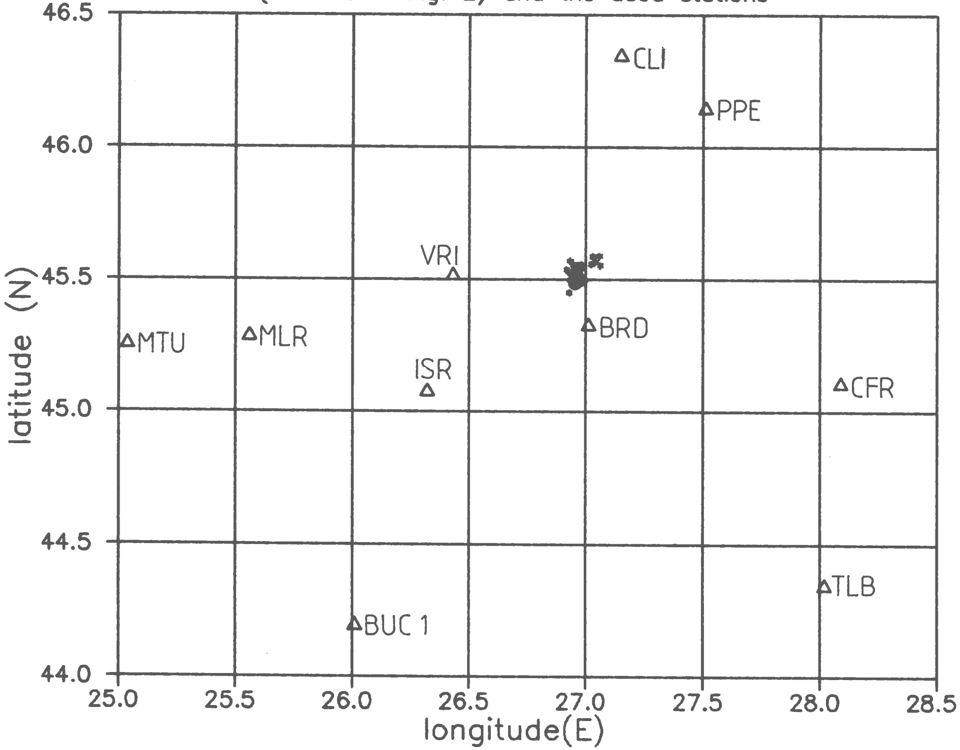
Fig. 1 — The epicentral area of the seismic sequence (detailed in Fig. 2) and the used stations



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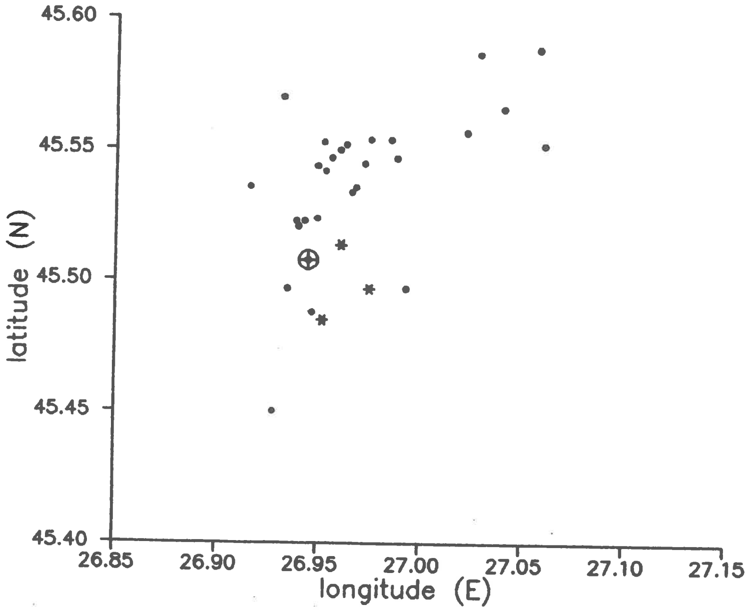

Fig.2 – Spatial distribution of epicenters
(⊕=main shock; * =foreshocks; • =aftershocks)

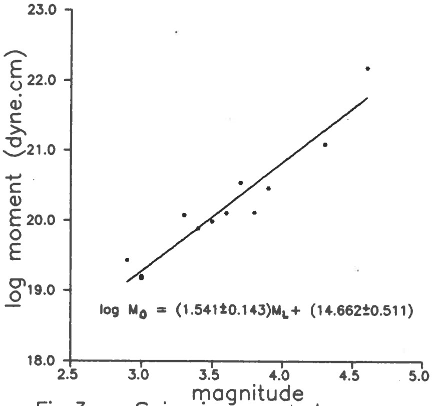

Fig.3 — Seismic moment versus local magnitude

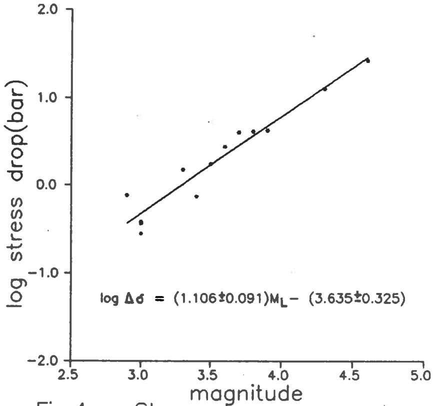

Fig.4 — Stress drop versus local magnitude

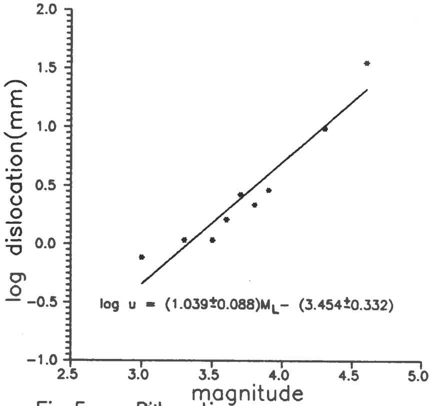

Fig.5 — Dislocation versus local magnitude

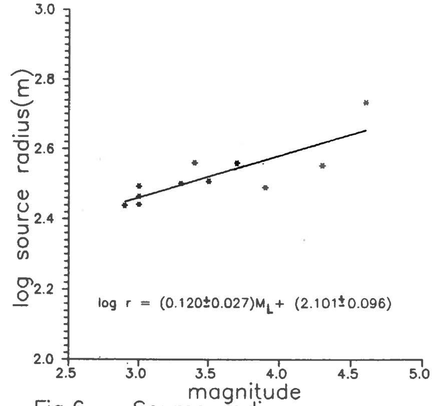

Fig.6 — Source radius versus local magnitude

INTENSITY ASSESSMENT FROM OFFICIAL DAMAGE SURVEYS: AN EIGHTEENTH CENTURY CASE IN CENTRAL ITALY

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After the 1741, Fabriano earthquake the Papal government resorted to the compilation of official damage surveys performed by technicians ("Periti") in order to assess the financial cost of the reconstruction and to evaluate how to distribute official subsidies among damaged communities. These surveys regard seventy localities and are of two kinds: those which damage and those that give only the repair cost. It has been performed an analysis of these detailed historical data to assess intensity in terms of MSK scale.

To assess intensity by means of MSK scale it is needed to know the types of structures and the number of damaged buildings over the total existing. It has been analysed the structures quoted in the surveys, comparing them with the architectonic and structural styles used in the past in this area. Even so it is not always possible to assign all damaged buildings to type A or B of MSK scale. The total number of buildings has been obtained in some cases using direct data, in some other deducing it from the number of inabithants. Assessing damage grade is in some cases difficult because of some ambiguities inside the surveys. The reconstruction of what happened in each locality it has been possible only with a margin of uncertainty: therefore, intensity oscillates between some figures, according to more or less conservative assumptions. The case of the village of Scisciano is an example where, out of 19 buildings, 3 are definitely type B and 16 may be attributed to class A or B.

conservative case (all buildings of type B):

types of buildings	number of buildings	grade of damage	%
B	1	2	0,5
B	3	3	16
B	15	4	79

I (MSK) = ≥ IX

non-conservative case (16 buildings of type A):

A	5	2	26
A	10	3	53
A	1	4	0,5
B	3	3	16

I (MSK) = VII

It is to be stressed that, using MCS scale, the intensity was VI-VIII.

This paper will be merged with Moroni, Improving the intensity estimates from historical records…, to be submitted for publication on "Terra Nova".

EARTHQUAKE-RESISTANT CONSTRUCTION IN SPAIN (XIII-XVITH CENTURY): PRINCIPLES OF HISTORIC SEISMICITY

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ABSTRACT

The studies on historical archives provide many information about the constructions in the past. From specific investigations on this subject, this paper establishes the existence of earthquake-resistant abilities in the Middle Ages and suggests some new directions to investigate from a historical point of view. I.A.G.P.D.S., Granada, Spain, develops several interdisciplinary investigations to obtain data from historical archives. We study two main groups of historical documents: public and private. Both cover the whole life in the Middle Ages in different areas and jurisdictions. Historical Archives in Spain are very common, but the documents they contain require an specific study by Paleographers and Historians, so the interdisciplinary investigations with them are very useful. Informations we study are related to historical constructions (methods of construction in the past, survival of ancient constructions and their preservation) and how search of this sort of information in historical archives. One of the most important topics of these investigations is the preservation of historical and artistic monuments, which represents a high cost to the governments.

1.- INTRODUCTION

The study of historical earthquakes that affected the humankind demonstrates the limitations of seismic catalogues and its update. The "Instituto Andaluz de Geofísica y Prevención de Desastres Sísmicos" (I.A.G.P.D.S., Granada, Spain) develops several investigations in order to clear the informations content in the seismic catalogues and complete them with documental data, published or unpublished. These researchs are interdisciplinary between seismologists, geophysicists, geographers and historians. Up to date some papers are published (ESPINAR and QUESADA, 1992; ESPINAR, MORCILLO and QUESADA, 1992) and several studies to the *VII Geodesy and Geophysics National Spanish Assembly (San Fernando, Cádiz, Spain. December 1991)* were communicated (especially "Aproximación a los sismos granadinos de los siglos XV y XVI. Metodología para su estudio" and "Materiales y sistemas constructivos de zonas sísmicas granadinas en los siglos XV y XVI"). F. Vidal, M. Espinar, J. D. Morcillo, J. J. Quesada and M. Feriche, members of the I.A.G.P.D.S., develop an interdisciplinary research named *Materiales y sistemas constructivos en el Reino de Granada* (*Constructive materials and systems in the Kingdom of Granada*).

According to the informations obtained from historical documents we realized that we need a correct evaluation of damages caused by earthquakes in several towns of Spain. In order to a best appraisal of the documental data we thought that the first step should be to get a better knowledge of the systems of construction in the past times. If we know exactly the constructive and earthquake-resistant characteristics of each historical buildings we will value more accurately the damage/intensity ratio, that seismic catalogues sometimes ascribes from irregular historical sources.

The study of historical construction systems provides informations that can be used in the preservation of monuments of artistic and historic interest. Moreover, this data can help to estimate the present resistance of all those buildings built according to past construction systems, so scarcely known today. Present seismic building codes in several countries just refers to materials such as steel or concrete, but they don't protect those buildings using other materials (adobe, rubblework, stone, etc.). Some of this constructions survives in wide areas of Spain and they need active help to avoid future earthquake damages.

Constructive principles in the Kingdom of Granada in the XIIIth and XVIth century were analyzed in order to get more immediate results. The region selected for study comprises the southeastern Spain, a well-known moderate seismic area with very destructive earthquakes in the past.

This paper make reference to the historical view of the problem of preservation and is an advancement of the investigations in progress. It doesn't try to value the earthquakes used as examples and authors are not responsible for the data collected from others publications.

2.- HISTORICAL ARCHIVES

The lack of specific and general bibliography about the topics on research, particularly about constructive systems in the Middle Ages, confirm us the need of using the documents of local and state historical archives.

There are two main groups in the historical documents: official and private documentation. This differentiation is more important than it seems, because sometimes the effects of an earthquake in an area can be omitted in the official documentation related to the Crown or its representatives due to the main effects take place in an area which is not under royal jurisdiction but ecclesiastic or "señorial".

The official documentation refers to: reports sent from local authorities to central government institutions related to questions asked or not by the late, individual or collective requests related to disturbances in the relationship with the local or central government institutions, lawsuits mediating ordinary or special courts of justice, legal dispositions related to regulations of all the aspects of the life of the country, etc. Archives provides us, for example, testimonies on various topics, even by masons or stone cutters which provides details on construction (several interesting examples are present in Baza 1531 and Almería 1522 earthquakes), regulations on trade and offices in a city (e.g. "ordenanzas" or rules of Granada), etc. There is also great quantity of official documentation on irrigation, buildings, royal endowments, etc., that provides informations even on unknown earthquakes.

The typology of private documentation is varied and several kinds of private contracts are remarkable. These contracts were authenticated and confirmed by notaries, which participated in all the agreements between two parties. In this type of documentation we find dealing documents of buildings and properties, contracts with craftsmen to do some works in buildings (repairs, new constructions), public auctions to award public or private constructions, appraisal of these works,...

The official documentation is usually found in national and regional archives, as well as archives of some private institutions, while private documentation is guarded in local and church archives, and also for some ancient families. The notarial documentation in Spain is guarded in the known "Archivos de Protocolos Notariales"; almost every important city has one of these archives. Archives of religious centres can contain documents referred to their construction and the daily life as well as other places under their jurisdiction. In the following pages we will show some examples of the data extracted from different types of documents referred to the research in progress.

Those documentation remains unpublished and is out of the reach for those researchers not get known with it. It must be completed with others documents already published, such as contemporary chronicles, traveller's stories, etc.

One of the purposes of the interdisciplinary investigations based on this documents is to use the historical data to complete the Seismicity Studies and provide reliable informations to the seismologists and other scientists. Behind of this, we try to open new possibilities to archaeologists, art historians and curators in order to design active preservation of the artistic and historic buildings menaced by earthquakes, as well as to protect people living in areas which still use old ways to build.

3.- EARTHQUAKE-RESISTANT CONSTRUCTIONS IN SPAIN

The study of earthquake-proof buildings or the measures related to diminish damages caused by earthquakes is a challenge for the seismologists, engineers, architects, etc. It seems that this idea was born with the Modern Seismology and instrumental recording of earthquakes, but we can find quotations about it in documents and even in IXth century works of the islamic tradition, for example IBN ABI ZAR (1964) relates the construction of some buildings in Fez, Morocco, in XIIIth and XIVth centuries, such as the mosque.

In the geographical and cultural areas we study an active attitude to protect some buildings is proved. In the Lions Court in the Alhambra of Granada, built under the reign of Muhammad V (second half of the XIVth century), capital and shaft of columns are have lead joints to assure their flexibility. We have already study the 1431 earthquake (ESPINAR, MORCILLO and QUESADA, 1992) which caused the collapse of a part of the city walls but didn't affect the palaces in The Alhambra. This earthquake occurred a few days after a bloody battle between the Granadins and the troops of king Juan II of Castile, the battle of "La Higueruela". When earthquake take place Castilians were settled on the plain near the city and Granadins were set to surrender. The king of Castile raised the siege although he saw the walls of the Alhambra tumbling down.

In Muslim domains, which Kingdom of Granada in the Middle Age was a part, several authors wrote since IXth century about causes of earthquakes and the dangers of constructions in seismic areas (IBN AL-GAZZAR, 1974). Similar preventions were taken in Christian Spain, where constructive traditions are little different.

Certain documents in Gerona (NE Spain) indicate the importance of earthquakes in building designs. In 1416 local and ecclesiastic authorities of Gerona asked to several architects working in the Kingdom of Aragón their opinion about the project of the cathedral. This cathedral should have only one nave, but people thought that this work were unsafe. Some architects said that wide buildings with one nave tumble down when earthquakes and hurricanes, but most of the architects, like Gillermus Sagrera, one of the most famous, considered that earthquakes and winds of the region shouldn't be dangerous. The authorities thought that building will be "*stabile et securum si prosequatur tali modo et ordine, ut est ceptum, et quod terraemotus, tonitrua nec turbinem ventorum timebit: tum quia ex opinione multorum artificaem praedictorum constat, dictum opus navis unius fore solemnius*". Finally, the cathedral was built with one nave, as today we can see; this is the wider nave never done in a gothic building.

However, popular constructions scarcely ever are studied and we can know many things about them by means of historical archives. We have found that foundations were considered very important; they were done with stone and lime. Foundations were at least 1 m. deep in a two-stories building and 4 m. height. Usually, stone walls have more lime than rubblework or sand walls. Roofs usually are made in timber and tile with two slopes. Wood frame buildings are not very common, but XIVth and XVth centuries spanish carpenters know very well how to do it. This is a cheap and resistant construction widely used in the Mediterranean Sea during many centuries (MOLIOTIS, 1956; PORPHYRIOS, 1971; SCHAAR, 1983; TOBRINER, 1974).

The churches and mosques are the biggest buildings and usually their foundations have around 1 m. depth or more. Rubblework is used in walls, which are reinforced with buttresses, and the corners are made in stone. Military constructions are made in rubblework with reinforcement in stone. This kind of work is easy and fast to do, but tumbles down because their height. In 1531 the castle of Baza (NE of the province of Granada) were almost completely destroyed by an earthquake that killed almost 1.000 people in this city.

There are two types of constructions depending on the use of the building. Palaces and cathedrals use more sophisticated techniques, but houses and other buildings benefit from safe and cheap well known constructive traditions so almost every building has at least a minimum protection, which we can't say it about all the buildings we are living now.

4.- NEW DIRECTIONS

In previous pages we have tried to show usefulness of data contained in historical archives in order to widen informations of seismologists. This kind of interdisciplinary investigations can be useful in several ways. However, we think that the first objective is to assure a suitable protection for the areas menaced by destructive earthquakes. At the same time, studies must extend geographically to diminish seismic risk.

The historic and artistic monuments can take advantage of experiences in earthquake-resistant construction in several countries with similar constructive traditions. The study of ancient constructive traditions need to know their earthquake-resistant abilities.

The documents provide to seismologists interesting informations that can help them to evaluate correctly intensity, and magnitude of no instrumental earthquakes, information very need to determinate areas exposed to destructive earthquakes.

We think is very important that scientists involved in earthquake prevention will share its experiences in order to contribute decisively to diminish the damages caused by earthquakes. This is our hope.

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IMPROVING THE INTENSITY ESTIMATES FROM HISTORICAL RECORDS BY INVESTIGATING SOURCES ON TYPOLOGIES AND NUMBER OF BUILDINGS

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The problem tackled is about the use of an indirect historical source to solve the uncertainty of the intensity estimate for Orciano, the most damaged locality by the 1846 Tuscan earthquake. This event is listed in the Italian Catalogue (Postpischl, 1985) with I_0=X MCS, that is the highest intensity in the seismic history of the area. A first study (Albini et al., 1991) used a direct source (the government surveys), that had some limits. First of all, some surveys did not supply less damage descriptions; furthermore the surveys did not distinguish the buildings in the village from those in the country. In spite of the attempts to fill in these gaps, the intensity estimate for Orciano remained uncertain between degrees IX and X MCS. So, the research turned to retrieve sources that could supply auxiliary information, like those on the settlement of the Orciano before 1846, the typologies of its buildings and their distribution. The cadastre compiled around 1823 (ASPi, 1823ca) is formed by a list of all the buildings and maps of the village and surrounding country. This source gives no information about building typologies, so it is difficult to apply the MSK scale. In spite of this gap, using the cadastre one is able to SEPARARE the village buildings from the country ones, so that data on damage in Orciano obtained from the surveys can now be interpreted as it is shown in the table.

data	number of	buildings	percentage of damaged buildings			I
			heavy damage	damage	low damage	(MCS)
Albini et al. 1991	total	113	62	30	7	IX-X
new research	total	94	66	19	4	IX-X
	village	52	50	31	8	IX
	country	42	85	5	-	(X)

The data of the total has not changed, but the discrepancy between village and country is remarkable. The data from the village, a limited area more suitable for intensity assessment, leads to an intensity of IX. Furthermore, in some cases cadastre maps have allowed to cross-check historical records with today evidences.

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This paper will be merged with Monachesi, Intensity assessment from official..., to be submitted for publication on "Terra Nova".

A "TIME-CLUSTER" OF EARTHQUAKES IN THE APENNINES, AT THE END OF XIII CENTURY

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This paper describes the results of the cross-analysis of a section of the Italian seismic catalogue that lists, between 1292 and 1294, at least six relevant events located in different areas of the Northern and Southern Apennines. Though relevant, these events are but poorly known: only one intensity point is available for each of them and most data are taken from unreliable sources.

Past catalogue compilers have often used, acritically, single data and second-hand, unchecked sources, and also different set of sources for each event. A straight translation of single and unreliable data into epicentral locations can bring about strange results such as in the case of the 1292 'Val Bivano' event, which has been located by the catalogue in Tuscany, where there is no locality or area recognizable as the 'Val Bivano' quoted by the catalogue's source.

To avoid errors, duplications and loss of information it seems preferable not to study a single earthquake at a time but, if possible, a 'family', that is to keep in mind all the earthquakes that fall inside a selected space/time-window. This procedure has been followed in the case of the Apennine time-"cluster" of earthquakes, with encouraging results: at least four earthquakes have turned out to be fakes, produced by misreadings of the original data on the part of later authors. The two remaining earthquakes have been re-dated and relocated. The first one occurred in Tuscany, probably in July/August 1293: it remains rather poorly known but there is no serious reason to doubt about its happening, as it is mentioned by two independent contemporary sources. The second event happened in Southern Italy, probably in September 1293: a careful re-reading of already known, but until now never fully exploited sources, has permitted to retrieve some 'lost' intensity points. This has been possible at low cost, by the critical use of original sources, without planning any large-scale search for really new data.

This paper will be submitted for publication on "Terra Nova".

THE SYSTEMATIC PROCESSING OF SEISMOLOGICAL COMPILATIONS AS AN INTRODUCTORY STEP TOWARDS THE HISTORICAL INVESTIGATIONS OF MAJOR EARTHQUAKES

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More than 300 major earthquakes which occurred in Italy from 1000 to 1880 have been investigated through a procedure called "Analysis through the compilations" in order to provide them with a preliminary intensity map. This procedure has been defined by the Working group "Macroseismic" of the Italian National Group for the Defense against Earthquakes (Stucchi, 1991).

As a great number of earthquakes or families of earthquakes had to be studied and in this project have been involved about 15 Research Unit, it was necessary to define a common procedure comparatively quick and homogeneous.

This methodology tried to met this two conditions:

1) Studying earthquakes starting from the information coming from the most important seismological compilations like Baratta (1901), Bonito (1691), Perrey (1848), etc. The authors of these compilations used in facts a great numbers of sources that are often not directly known or misinterpreted in the successive studies.

2) Fixing in this procedure some fundamental steps.

Each one of these steps represent essential points for a systematic processing: *a)* the choice of a suitable (for time and space) set of compilations; *b)* the identification and the retrieval of the original sources; *c)* the compilation of a filiation scheme among records, linked to a careful reading of the sources; *d)* the drafting of tables for comparison among all records of each source and localities to which this information refers.

Starting from these tables, it is possible to produce an intensity map, reliable as it is supported by all data used to compile it.

Using this methodology it becomes evident how the corruption of the sources or its loss, even partial, can significantly modifies a record. Of course, even if we had often good results, the "Analysis through the compilations" it is not an exhaustive study, but a sort of bibliographic research that could be prepared as a preliminary approach to a following extended study.

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FAKE QUAKES IN ITALY THROUGH CATALOGUES AND SEISMOLOGICAL COMPILATIONS: CASE HISTORIES AND TYPOLOGIES

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As it is well known, parametric catalogues list fake records created on the basis of uncareful handling of historical information. In the Italian catalogue (Postpischl, 1985) some tens of fake quakes have been found inside the time-window 1000-1690.

By means of the "analysis through compilations" (GNDT Macroseismic W.G., 1993) about 40 events with epicentral intensity between degree VI and IX of the MCS scale have been proposed to be deleted as fake quakes; 11 other fake quakes were pointed out by other Italian investigators. These 51 events can be included into two basic typologies: a) duplications of true events, due to reading mistakes by the compilers, or to the spreading of data relating to other earthquakes, made by the original source or by compilers themselves; b) other events (landslides, floods, storms, one explosion, etc.) interpreted as earthquakes .

In many cases it is difficult to find the "turning point" of the information: it is often a matter of progressive corruption of sources that leads to a loss of data or to a wrong extension of real event.

In some cases, the mistake depends on the presence of discordant dates in the most ancient sources, that XIX century compilers of catalogues had no means to verify.

In other cases, compilers of Wonder-catalogues of the XVI century, like Lychostenes and Bardi, are at the origin of fake quakes.

Frequently, the XVIII and XIX century historiography exaggerated interpretations of data: wrong dates, wrong reading of the most ancient sources, wrong interpretation of described events, etc.

The most interesting aspect in this kind of studies, is the possibility to discover mistakes thanks to a simple approach like the "analysis through the compilations".

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URBAN SEISMIC SCENARIOS: SYRACUSE (EASTERN SICILY) FROM THE TWELFTH TO THE NINETEENTH CENTURY

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INTRODUCTION

On the basis of the frequency and gravity of the seismic events that have taken place in the past, Eastern Sicily is considered to be one of the areas of greatest risk in Italy. This region, today densely populated, has a rich inheritance of buildings, art, archaeology and industry. The area in a radius of 50 km around Syracuse has, in the course of history, been affected by 132 seismic events, ranging in severity from II to XI on the MCS scale. According to the *Catalogo dei terremoti italiani* (Rome 1985) the most destructive earthquakes occurred in 1169, 1542, 1693, 1757 and 1846 and are estimated to have been of an intensity at their epicentres equal to or greater than IX on the MSC scale. The research carried out on these earthquakes has made it possible to look again at the parameters relating to the seismicity of Syracuse in the light of new data and within a context of effects on a territorial and an urban scale. Here we will confine ourselves to giving, for each event, the most significant results.

DISCUSSION OF THE RESULTS

The earthquake of 4th February 1169 is described in numerous Latin sources, contemporary with or written shortly after the event. There is also occasional reference in Arab and Greek sources. The contemporary descriptions of the effects give us, however, little more than a summary picture from which we can only approximately localise the area of most severe damage. Thus the limits of the area most seriously affected are hypothetical.

Little is known about Syracuse at the time of this earthquake. The only known indication of the size of the urban population comes, more than a century later, from a census of 1277 (a period when the population was falling) which lists little more than 800 "hearths". We can hypothesise that the population must have been only slightly over 3000 inhabitants.

The sources say that the earthquake destroyed (caused to collapse, or merely damaged?) «part» or «the greater part» of the town – in other words, in the worst possible case, 50% to 60% of the buildings (about 400-500 houses).

Very little is known about the houses of the ordinary people of Syracuse in the mid-twelfth century: medieval urban archaeology has not yet provided us with data that can be used in this way. The contemporary historian Falcando describes the appearance of the worst-hit areas as a «heap of wood and stones», this probably refers also to Syracuse. Thus we have stone and wood, in an urban site still following the original Greek plan and only partly modified by the arrival of the Arabs.

We would estimate that the seismic effects in Syracuse were equivalent to IX on the MCS scale.

The earthquake of 10th December 1542 represents an interesting seismic event that has hitherto attracted little attention from seismologists and historians. The earthquake affected particularly the hilly and mountainous inland areas of the Iblei Mountains. The destruction was massive, not least because a common denominator of the urban buildings was their altimetric discontinuity and the irregularity of the walls due to a succession of building campaigns.

At the time of the earthquake, Syracuse had a little under 12,500 inhabitants and probably about 2300 houses. We have, however, no way of assessing the state of conservation of the buildings. The documentary sources concerning Syracuse contain precise information only about damage caused to a few particular buildings, making very few references to ordinary town buildings. These we have tried to reconstruct "inductively" by looking at all the administrative measures taken over a period of more than fifteen years after the earthquake. In Syracuse the houses, rather than collapsing completely, were severely cracked or had walls detached. This widespread effect would have made many houses uninhabitable. The areas of the town worst affected lay to the south-west, but there is no evidence to indicate that other parts of the town did not suffer lesser types of damage.

Following the earthquake Syracuse went through a difficult economic phase with rises in the prices of goods and property. This situation had the effect of discouraging reconstruction, prolonging the abandonment of the city by more than half the population. We have found, in this case, that seismic effects of a strength of no more than VIII on the MCS scale can, in particular situations where the economic and social situation is essentially precarious, transform an earthquake into a seismic disaster.

The earthquake of 11th January 1693 is that has engraved itself most deeply in the memory of the people of Sicily. There are many reasons for this: the size of the area affected, the severity of the effects and the unusually efficient planning that characterised the period of reconstruction, that was to give many towns of south-east of the island their new Baroque appearance. We are dealing here with a comparatively rare historical case, where an earthquake represents an opportunity for the development and revitalisation of a previously stagnating economy.

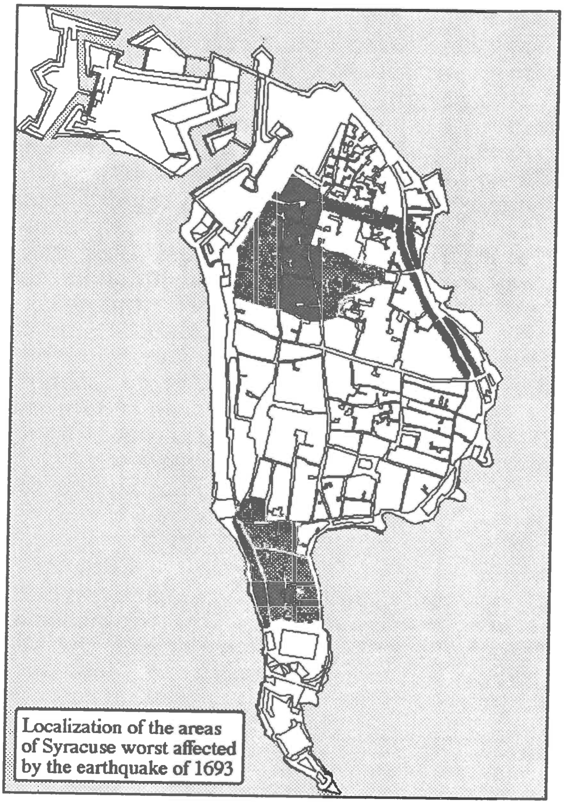
This interpretation has been reached after the examination of a very considerable quantity of archival and memorialist documentation, covering the whole of the area affected – that is, from the southern-most tip of Calabria down to Malta on the east side and from the east coast to Palermo.

The period of seismic activity started on 9th January with a first devastating shock that caused buildings to collapse or crack in all the inhabited centres of south-east Sicily, from Catania to Noto. The effects of this first shock on Syracuse are estimated to be not more than VII on the MCS scale. But if an evaluation of the effects were to be applied to the urban area of present-day Syracuse, one would have also to include in the scenario that part of the territory that was country in the seventeenth century: this would mean that the estimation of intensity would rise to VIII MCS.

The most destructive struck two days later, on 11th January, a vast area that was already seriously shaken and damaged. Looking only at the area of major damage, an entire territory of more than 14,000 sq. km was devastated by this earthquake. We have estimated the intensity in more than 140 different places. Here we will describe the seismic scenario relative to Syracuse.

If we include the extra-urban areas, the shock of 11th January caused the death of 3500-4000 people in the Syracuse area, on a total of 17,000 inhabitants. Only a few thousand people remained in the city after the earthquake and they were subsequently forced by a public order to leave for hygiene reasons.

Concerning the seismic effects in the urban area (see the figure), it has been possible to specify precisely the damage for some categories of building: ecclesiastic, monastic, military. The more difficult aspect of the research concerns the ordinary town houses, a category that has tended to be ignored by the official sources in past centuries. According to the mayor of Syracuse, Ximenes, before the earthquake the area of Syracuse had some 3000 houses, the greater part of which were in good condition. It is very difficult to evaluate this judgement on the state of the houses. Other data concerning Sicily in this period indicate that the buildings were in a very bad condition. Ximenes recalls that 2500 houses collapsed or became uninhabitable and the remaining 500 were badly damaged.



Localization of the areas of Syracuse worst affected by the earthquake of 1693

The assessment of the damage suffered by Syracuse became, however, almost immediately a matter of controversy.
Even the contemporary sources do not agree: clear exaggeration or "reductive filters" are applied depending on the author's point of view or motivation, giving rise to exaggerated or minimising interpretations of the effects influencing successive historiographers right up to the present day.
Here we would like to mention particularly that recently some scholars have tried to reassess the seismic scenario in Syracuse on the basis of urbanistic arguments, adducing as proof that the planimetric layout of the town remained more or less unaltered after this earthquake. But the analysis of the overall process of reconstruction carried out in the whole region in the following decades has clearly demonstrated that the types of reconstruction followed various different patterns depending on circumstances. These can be grouped into three typical situations:
1 – towns rebuilt on new sites;
2 – towns rebuilt *ex-novo* on the old site, changing the planimetric scheme;
3 – towns rebuilt following the original street plan.
This last was probably the solution adopted in those towns where the destructions hadn't been complete, and therefore in Syracuse, but this does not mean, however, that there was only a limited number of collapses.
The very large number of victims in Syracuse – at least 2000 – must be due to widespread collapses, involving many houses. It is precisely because they are

only ordinary town buildings, anonymous and modest, that such houses can easily be omitted from direct quotations from the sources.
Thus, we cannot, if we are to observe the "rules of the game" of historiography, assert that the only collapses to take place were those of buildings specifically mentioned in the documents or evidence of whose reconstruction is marked by plaques or epigraphs.
We would estimate that the effects of the shock of 11th January 1693 in Syracuse were equivalent to IX on MCS scale.

The earthquakes of 6th August 1757 and 7th August 1846. Finally, moving away from the generally-held opinions about the seismicity of Syracuse, we have been able to demonstrate that these two seismic events - considered to have registered IX in the MCS scale - never occurred.
This misunderstanding is due to errors derived from reports in foreign newspapers, restated by A.Perrey (*Mémoire sur les tremblements de terre de la Péninsule Italique*, Brussels 1848) and then by M.Baratta (*I terremoti d'Italia*, Turin 1901) and perpetuated by the history of seismology. In the case of the earthquake of the 6th August 1757, the shock should be reassessed at V on the MCS scale. As for the earthquake of 7th August 1846, it did not happen at all.

CONCLUSION

To conclude, the research briefly described here has made it possible to come to new conclusions about the seismicity of Syracuse in relation to the major events affecting that town between the twelfth and nineteenth centuries. The number of the major earthquakes has been changed from 5 to only 3 (see the table).

Comparing intensity values (using MCS degrees) of Syracuse, before and after this research.

events	pre-research estimation	revision of the results
4th February 1169	X	IX
10th December 1542	VIII-IX	VIII
11th January 1693	X	IX
6th August 1757	IX	V
7th August 1846	IX	fake earthquake

This necessitates a change in the statistical calculations as to the time-lapse between events and the estimation of seismic danger.
In addition, the detailed evidence concerning the effects on the urban area have made it possible to clarify the real extent of the damage caused by the earthquake of 1693. We have shown how there exists a higher level of danger for those areas once contryside outside the urban area. It was to be in these areas that the present-day city of Syracuse was to develop.

The data of this study was collected during the research regarding major earthquakes in Sicily and Calabria. This research was coordinated by E.Guidoboni on be behalf of the ING (National Institute of Geophysics), and the results of which are available in the PERSEUS Data Bank. For a more expansive and indepth study or a list of documentary sources consult E.Guidoboni and D.Mariotti, I terremoti dell'area siracusana e i loro effetti in Ortigia (in press).

THE "MAGGIOL" MAP AS A SOURCE FOR THE INVESTIGATION OF THE 1564, NISSART EARTHQUAKE

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This paper discusses the problems of the use of peculiar sources, such as depicted maps, in the historical investigation on earthquakes. In particular, the aspects of the intensity assessment which come from the location problems, not infrequent for medieval and, even, for modern earthquakes, are underlined. The so-called "Maggiol" map, describing the effects of the 1564, Nissart earthquake, is considered as one of the first "earthquake maps", and has been studied by several authors (Baratta, Almagià, Cadiot). One sample of the map is printed together with the German text of a letter by "F. Mogiol", supposed to be a Genoese merchant, describing the effects of the earthquake. Map and text are, still, one of the main source of information for the Nissart earthquake, at least for some localities. Many versions of the letter exist, showing slight differences (see table).

Table - Comparison among main elements of the versions of the "Mogiol" letter

locality and date of issue	**Nürnberg, 1564**	**ms.**	**Dillingen, 1564**	**Augsburg ,1565**	**Augsburg, 1566**
present location	Erlangen Library	Zurich Library	Wolfenbüttel Library	Wolfenbüttel Library	
language	*German*	*Latin*	*German*	*German*	*German*
date of the letter	XVII AUGUST MDLXIIII		18 Augusti 1564	17 Augusti	18 Augusti Anno 1566
date of the event	XX. IULY [1564]		zwantzigte tag des Monats July	20 Julij [1564]	20. Juli
locality names	ROCCA MARINA. REPELLA. SANDALINGI. ROCCA BALLIERA. VILLARET. MORENA und ROCCIA.	Roccamanciana. Regola. Saldamin. Rocca. Billiorum. Villaretum. Murena.	Rocca Marina, Reple, Sandalim, Rocca, Bigliera Villaret, Morena.	Rocamarina / Repella / Sandalingi / Roccaballiera / Vilaret / Morena / unnd Roccia	Rocca Marina / die anderen heissen Sandalina / Rocca Belgina / Vilant / Morena und Repla
	VILLAFRANCA	Villa Frantiae	Villa franca	Villafranca	Villa Franca

The investigation carried out in the frame of the EC project "Review of Historical Seismicity in Europe" has shown that it is possible that map and letter don't belong to the same author. Moreover the map, which shows some relevant geographical inconsistencies, has turned out similar to some "official" maps of the end of the XVI century, rising some doubts about the fact that it might have been drawn by an unskilled merchant.

FURTHER RESEARCH ON THE HISTORICAL SEISMICITY OF TUNISIA

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During five years some research has been devoted to the historical seismicity of Tunisia, using Tunisian and European sources. First results, however unpublished, have been given at the Joint EGS-ESC-CEC Symposium (Bologna, March 23-24, 1988). While some problems have been solved since, question marks are still numerous. Let's proceed chronologically, over nearly two millenaries. The seismicity of the Antiquity has been emphasized first by classical catalogues, then by archaeologists with an outstanding love for earthquakes, sometimes handled as a kind of deus ex machina. Actually a major "event" from the beginning of the fifth century, the famous "Utica quake" hung until the last years as a Damocles' sword over north-eastern Tunisia, with its intensity X or so. Actually it seems to be a typical "fake quake". Of course, Tunisia did not escape the well-known 365 earthquake frenzy of some archaeologists. The same frenzy also led the hypothesis of the destruction of Hadrumetha/Sousse by an earthquake in 306-310, a hypothesis soon doubted by another archaeologist. Some events are known from the glorious centuries of Ifrikiya, around the 10th century. Then catalogues show a huge gap from 10th century until the midst of the 19th century, with, however, one major exception, the 1758 earthquake, considered destructive at Tunis, with thousands of victims, acting once more as a Damocles' sword. Unfortunately, until now no reliable testimony of such an event has been found, despite rather intensive research. Actually some events occurred during this gap, one, it seems, in the 15th century, others in 1735 (Tunis), 1834 (Sousse), etc. Knowledge of events in the second half of the 19th century is progressing quickly. Since the end of the 19th century most events have of course been recorded. However, strangely enough, some of them, although listed by annual reports of the meteorological department, have escaped catalogues. Whatsoever, intensive work has been devoted to this period, until the thirties, mostly through newspapers (with an outstanding contribution by Mr. Zenati). Of course the knowledge of the seismic activity of the different regions of Tunisia is unequal, with many problems of interpretation in the border region with Algeria. Anyway, a clearer view of Tunisia's seismicity arises. On the whole the frequency of events had been underestimated, while intensities had been overestimated. Events of some importance, say over degree VII, are so few and gaps so important that more attention should be paid to minor earthquakes possibly offering seismotectonic clues, with emphasis on sequences for proper seismological comparisons and interpretations. Besides modern instrumental records, reinterpretation of old records is needed; tentative maps of epicentres and maximal known intensity could now be drawn, besides a seismotectonic sketch.

This paper will be submitted for publication on "Terra Nova".

KNOWN AND UNKNOWN EARTHQUAKES THROUGH SOME EUROPEAN PERIODICALS OF THE EIGHTEENTH CENTURY

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In the 18th century, periodical press is well spread throughout Europe and since the 19th century, pioneer seismologists used the information coming from the press for their lists of European earthquakes. In the same perspective, a systematic reading of some periodicals published during the 18th century has been carried out in the frame of the EC project "Review of Historical Seismicity in Europe". The periodicals are the "Gaceta de Madrid" for the time-window 1701-1750, "Gazeta de Lisboa"(1715-1751) and "Mercure de France" (1732-1763). "Systematic" means that all the published numbers available at the National Library of Madrid have been consulted and that all the information related to earthquakes has been retrieved. The dataset contains information on European and Middle East countries. Each periodical received correspondences from capitals and other important towns of many European countries, for instance: London, Bruxelles, Amsterdam, Milan, Genua, Florence, Roma, Naples, Belgrado, Istanbul. Some basic questions guided the analysis: For which earthquakes do periodicals supply information? Destructive ones only? Is it "original" information? Which is the reliability of their records? Since around the 75% of the information on earthquakes in the time-window 1701-1763 come from Italy, the data have been compared to the space-time and intensity parameters of the Italian seismic catalogue. The comparison showed three kind of data: a) coherence between press and catalogue (40%); b) uncertain link between press and catalogue (20%); c) earthquakes not included in the catalogue (40%), about one third of which are reported as damaging ones. Some cases: a) 1751, Nov. 21, Mar Ligure, Io=VI MCS (Postpischl, 1985): "Gazeta de Lisboa" (18-1-1752) gives precise information on the perception of the earthquake in Milan; b) 1732, Dec. 1, information from Napoli and Gallipoli from "Gazeta de Lisboa" (12-2-1733) and "Mercure de France" (12-1732): possibly an aftershock of the well known Irpinia quake of November 29 (Io=X MCS, Postpischl, 1985); c) 1726 Oct., L'Aquila, from "Gazeta de Lisboa (26-12-1726) and "Gaceta de Madrid" (19, 26-12-1726): this event is "unknown" to the Italian catalogue. Data have now to be compared with information from other sources and enriched by ad hoc research.

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This paper will be submitted for publication on "Terra Nova".

ANALYSIS OF HISTORICAL SEISMOGRAMS FROM THE POTSDAM STATION

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INTRODUCTION

On the 17th of April, 1889 E. v. REBEUR-PASCHWITZ recorded the first teleseismic event at Potsdam and Wilhelmshafen. It was the beginning of the age of instrumental based observations in seismology. In the next few years the first seismological stations were already in operation.

In the framework of the Royal Prussian Geodetic Institute the seismological station Potsdam (52,380 N; 13,068 E) started its routine observations on the 1st of April, 1902. Continuous observations were carried out under the supervision of O. HECKER, the first director of the station and a bulletin was edited. The old registrations and the bulletin were and still are an important source for scientific investigations, especially for the global seismic risk assessment for the beginning of this century.

In comparison with the catalog established by DUDA et al. (1990) for the Göttingen station the old data set of the WIECHERT-seismograph (horizontal pendulum, 1000 kg) was reanalyzed. This seismograph was working continuously from the 13th of October, 1903 until the closing of the station on the 3rd of September, 1954.

INSTRUMENTAL PARAMETERS

For the time period 1904-1954 the instrumental constants of the 2 components of the WIECHERT were recorded in the bulletins. Their change over time was observed. It is remarkable that since 1933 no significant changes are observed in the magnification values. After a test period which lasted until 1910 the eigenperiod of the WIECHERT was within a range of 6 to 9 seconds. For the time period 1911-1954, avarage parameters were calculated (Table 1).

Table 1: Avarage parameters of the WIECHERT-seismograph of Potsdam Station (1911-1954).

parameter	E-component	N-component
attenuation ratio	3.48 : 1	3.38:1
eigenperiod, T_0 [sec]	6.86	7.12
magnification	266.76	263.86
attenuation, D_s	0.3689	0.3615

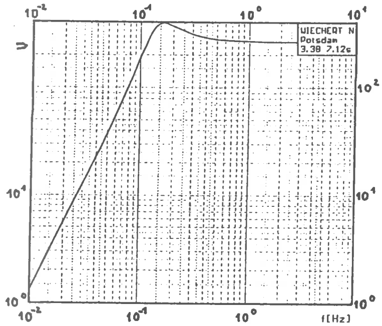

Figure 1: Response function for the Potsdam WIECHERT-seismograph (N-component)

On the other hand between 1905 and 1910 there was no check of the seismometer parameters. In 1910 relatively high deviations from the initial parameters were observed. The reanalysis of the data from

this time period is therefore critical. The reconstruction of real instrumental parameters of that time on the base of available data and informations is impossible. For the time period 1917-1924, one can expect also several uncertainties.
Nevertheless, on the basis of the average instrumental parameters a response function was calculated (Figure 1). It was used for the determination of the amplitude of the ground motion.

CALCULATION OF MAGNITUDES

The estimation of the magnitude as a standard parameter for energetic classification of a seismic event is one of the classical tasks of a seismic survey of a station or a seismic network. For the seismically active period of the beginning of the century magnitude determinations of only few stations exist. This study is directed to enlarge the data set. Here the classical magnitude formulae

$$M = \log (A/T) + f(D,T) \quad (1)$$

where A: amplitude of the ground motion, T: period and D: distance from the source, was used. The term f(D,T) is the magnitude calibration function. There are several calibration functions worldwide but no generally accepted standardisation exists. For the calculation of the so called Potsdam magnitudes, calibration functions listed in table 2 were used.

Table 2: Magnitude calibration functions.

wave type	calibration function	notation
P-wave	CHRISTOSKOV, KONDORSKAYA, VANEK (1983)	POT
	BATH (1969)	DUDA1
	GUTENBERG (1945)	DUDA2
surface waves	CHRISTOSKOV et al. (1983)	POT1
	KARNIK et al. (1962)	POT2
	GUTENBERG, RICHTER (1956)	DUDA1
	NORTMANN, DUDA (1982)	DUDA2

The function of KARNIK et al. (1962) was chosen for its successful use in the routine seismic survey at the Central Institute of Physics of the Earth at Potsdam. The function of CHRISTOSKOV et al. (1983) based on a comprehensive recent data set and recommended by the IASPEI as a standard function was therefore selected.

RESULTS

For 529 seismic events with an expected surface wave magnitude above 6.0 a Potsdam magnitude was calculated. Figure 2 shows an example of a calculated data set.

Figure 2: Example for a data set.

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****** 7 ******************************************************
1904JUL 1 OT: 13:27  42.5 N  145.2 E   HOKKAIDO, JAPAN, REGION
DISTANCE: 76.8°
MAG PH : EAST : 7.47 (A: 9/T: 6.0)  NORTH : 7.07 (A: 6/T:10.0)
MAG P:    POT  : 7.27     DUDA1: 7.04     DUDA2: 7.79    (4.40)
MAG LH1: EAST : 6.26 (A:10/T:12.0)  NORTH : 6.31 (A:14/T:15.0)
MAG LH2: EAST : 6.35                NORTH : 6.40
MAG L: POT1:6.29  POT2:6.37  DUDA1:6.99  DUDA2:6.82    (19.60)
MAG FROM OTHER CATALOGS:   MIN: 7.7    MAX: 7.7
```

A: Amplitude
T: Period
PH: horizontal component for POT
LH1: horizontal component for POT1
LH2: horizontal component for POT2

(notation see Table 2)

The parameters for the two components of the WIECHERT-seismograph are different. The effect on the magnitude calculation is shown in figure 3.

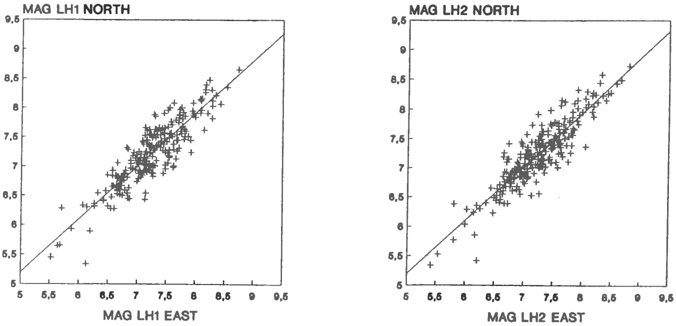

Figure 3: Correlation between the component-wise calculated magnitudes with help of CHISTOSKOV's [LH1] and KARNIK's [LH2] calibration functions for surface waves.

For surface waves the correlation line shows a slope of 45 degrees. The scattering is in the order of one magnitude unit. This value is typical because no corrections were applied. For the P-wave we could not obtain a correlation as good as the one for surface waves. Due to the small amplitudes of P-waves the error in measuring amplitudes can effect the calculations of magnitude drastically.

Figure 4 shows the comparison of the Göttingen and the Potsdam magnitudes.

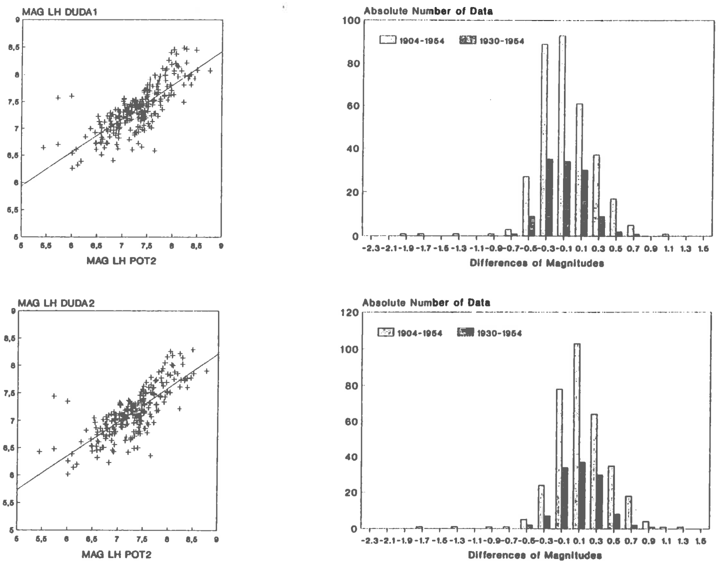

Figure 4: Comparison of surface wave magnitudes for Potsdam and Göttingen (left side: correlation; right side: histogram of differences for time periods 1904-1954 and 1930-1954).

The agreement between the Potsdam and Göttingen magnitudes is better for surface waves than for P-waves and it shows only a small scattering. The histograms show that there are big deviations of magnitude values for the time period 1904-1930 (up to > 1 unit). This is due to the lack of experience in exploiting the WIECHERT-seismograph (e.g. only 2 determinations of instrumental parameters until 1910) and problems connected with the First World War (e.g. the lack of trained people, financial problems of the Institute). All the calculations are summarized in the Potsdam catalog (KOWALLE, THÜRMER (1991)). In this catalog apart from the event data given by DUDA et al. (1990) are added the following parameters: (a) distance from the source, (b) magnitude values for the two components of P- and surface waves, (c) avarage magnitude values of each wave type, (d) Göttingen magnitude values, (e) maximum and minimum magnitude values from other catalogs. It is shown that the calculated Potsdam magnitudes are within the scattering of magnitude values given by other authors. A possible systematic deviation was not found.

CONCLUSIONS

The analysis of historical seismograms of the Potsdam station showed that bulletins and old seismogram data can be used for seismicity studies. It is possible to improve the global seismicity assessment with the help of this data. From this point of view it seems necessary to continue such investigations for other stations. Until now only strong earthquakes were reanalyzed. The analysis of existing local and regional earthquake records can give more information about the seismicity of distinct regions at the beginning of our century.

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THE VRANCEA (ROMANIA) EARTHQUAKE OF OCTOBER 26, 1802

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The earthquake of October 26, 1802 (H=10:55, φ=45.7°N, λ=26.6°E, h=130 km, Io=IX$^+$, M=7.5), which occurred at the Carpathian Arc Bend, in the Vrancea region, represented the subject of many studies (see References) because of its peculiarities (high intensity, large macroseismic area, important damage in Bucharest City, aftershock activity). Significant information on this earthquake are presented in Table 1.

The critical analysis of the information, included in different catalogues and in a series of original contemporary documents, some of them signaled for the first time, allowed to precise the characteristics of the main schock and of the aftershock sequence. The final parameters adopted are given in the last line of Table 1.

The detailed study of the seismicity of Romania shows that this earthquake was the largest generated in the Vrancea region, during the last millenium (stronger than that one of November 10, 1940/Io=IX, M=7.4).

The earthquake of October 26, 1802, known as "the great earthquake", was felt on a large area (more than 2 mil. km^2), from Moscow and St. Petersburg to Istanbul, and heavy damage were recorded in the Carpathian area and in Bucharest.

A new macroseismic map, using original contemporary documents, was drawn and the macroseismic field is compared with those corresponding to the major events occurred in this century (1940 Nov.10/M=7.4; 1977 Mar.4/M=7.2; 1986 Aug.30/M=7.0). We note the similarity among 1802, 1940 and 1986 events concerning the preferential radiation of seismic energy through North-East, as an effect of unilateral propagation of rupture.

The earthquake produced very heavy damage in Bucharest, where the high buildings were firstly affected (churches, towers and rich people houses). Documents of that time show that: "All the houses and churches were damaged and the upper part of Colţea tower, the jewel of the town, collapsed... In many places, cracks were noticed and sand and water went up from the ground... Only few people were killed". The duration of the shaking was about 1 minute. A general panic was observed in town.

The main shock was followed by a sequence of aftershocks from which the largest, of magnitude M_1=5.5, occurred after about 14 hours. It results a magnitude difference M-M_1=2.0 between the main shock and the largest aftershock. This value is very close to that one observed during the November 10, 1940 event (M-M_1=1.9).

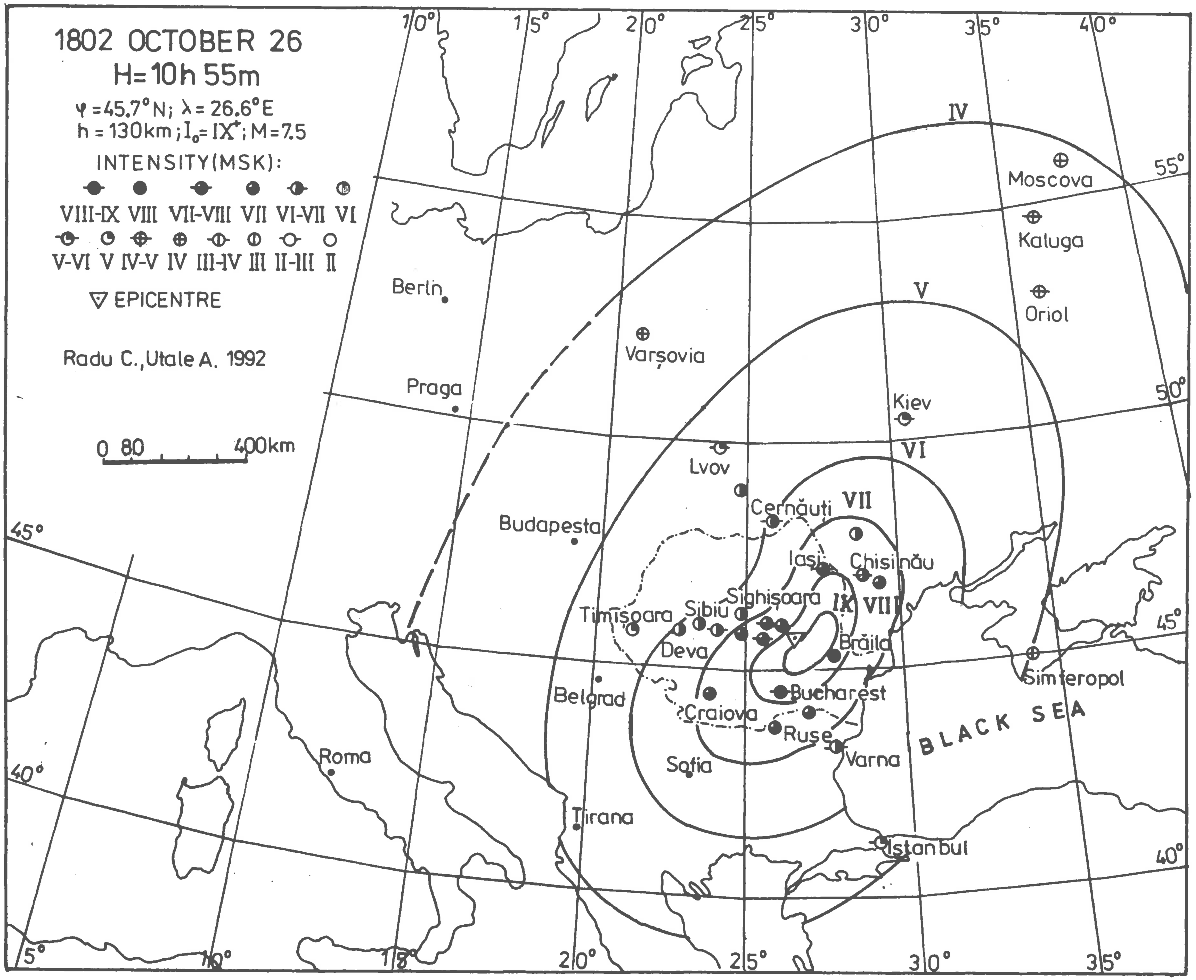
The recent results concerning this earthquake played an important role in the elaboration of the new seismic zoning map for the territory of Romania (STAS 11100/1-91). It is also useful to precise the seismic hazard in the neighbouring countries, as Republic of Moldavia, Bulgaria, Ukraine and Yugoslavia.

The earthquake of October 26, 1802 had a great importance for the definition of the ciclicity in the occurrence of strong intermediate earthquakes in the Vrancea region.

Table 1 - Significant information on 26 October 18o2 Vrancea earthquake

No	Date	Time	Lat. N^o	Long. E^o	h km	Seismic area	I_o	M	Remarks	Source
1	18o2 Oct.26					Romania/ Bucharest	X RF		Strongly felt on a large area	D/1896
2	18o2 Oct.26	1o:55				Romania			Strongly felt on a large area ("the great earthquake"). Bucharest: very heavy damage (uper part of Colţea tower collapsed; duration ≃ 2 min.); Aftershocks (3).	S/19o2
3	18o2 Oct.26					Vrancea			Strongly felt on a large area ($S \geq 2$ mil.km^2). Heavy damage at Bucharest, Iaşi, Braşov. Bucharest: I=VIII; duration ≃ 6o sec. Aftershocks. Identical with 1o Nov.194o earthquake. Isoseismal map.	P/1941, 1956
4	18o2 Oct.26	1o:55	45°51'	25°36'		Romania/ Braşov	≥IX		Strongly felt on a large area. Aftershocks. Isoseismal map.	R*/1952
5	18o2 Oct.26	1o:55				Vrancea			Stronger than 1o November 194o earthquake.	A/1961
6	18o2 Oct.26	1o:55	45.7	26.6	13o±	Vrancea	IX	7.2	Strongly felt on a large area Aftershocks.	R/1971b, 1974
7	18o2 Oct.26	1o:55± 1o	45.7 ± o.5	26.6± o.5	15o±	Vrancea	IX± o.5	7.4± o.5	r_8=12o(4), r_7=25o(4), r_6=41o(3), r_5=75o(7), r_4=13oo(4) km. Aftershocks.	KS/1977
8	18o2 Oct.26	1o:55	45.7	26.6	13o±	Vrancea	IX	7.5	The largest Vrancea earthquake. Aftershocks/M_1=5.5; δt_1≃14 h.	R/1979, 1992
9	18o2 Oct.26	1o:55	45.7	26.6	13o	Vrancea	IX+	7.5	The largest observed Vrancea earthquake. Similar with 1o Nov. 194o (macroseismic field, rupture process, aftershocks).	This paper

A=Atanasiu; D=Drăghiceanu ; KS=Kárník and Shebalin ; P=Popescu ; R=Radu ; R*=Réthly ; S=Stefănescu.


1802 OCTOBER 26
H=10h 55m
φ=45.7°N; λ=26.6°E
h=130km; I₀=IX⁺; M=7.5
INTENSITY(MSK):
VIII-IX VIII VII-VIII VII VI-VII VI
V-VI V IV-V IV III-IV III II-III II
EPICENTRE
Radu C., Utale A. 1992
0 80 400km
IV
V
VI
VII
VIII
IX
Moscova
Kaluga
Oriol
Berlin
Varșovia
Praga
Kiev
Lvov
Budapesta
Cernăuți
Iași
Chișinău
Sighișoara
Sibiu
Timișoara
Deva
Brăila
Belgrad
Bucharest
Craiova
Ruse
Varna
Sofia
Simferopol
BLACK SEA
Roma
Tirana
Istanbul
10°
15°
20°
25°
30°
35°
40°
45°
50°
55°
5°

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THE "WORKING CATALOGUE" OF THE NATIONAL GROUP FOR PROTECTION AGAINST THE EARTHQUAKES (GNDT) OF ITALY. PROBLEMS AND RESULTS OF A PRELIMINARY INVESTIGATION OF MAJOR EARTHQUAKES BEFORE 1690

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INTRODUCTION

After the publication of the PFG-ENEL catalogue (Postpischl, 1985) the problem of updating the seismic database of Italy has been considered by several points of view. In the same time, in Europe and the world, it has become clear that the catalogue records are nothing else but a very rough synthesis of many data, some of which can be used directly, such as - for instance - the intensity data-points. Consequently, catalogues are just the opposite of what many users believe. Instead of representing the primary data, they represent the tops of complicated pyramids which incorporate data, procedures and choices; that is, they are the final output of a research, the main steps of which are seldom transparent.

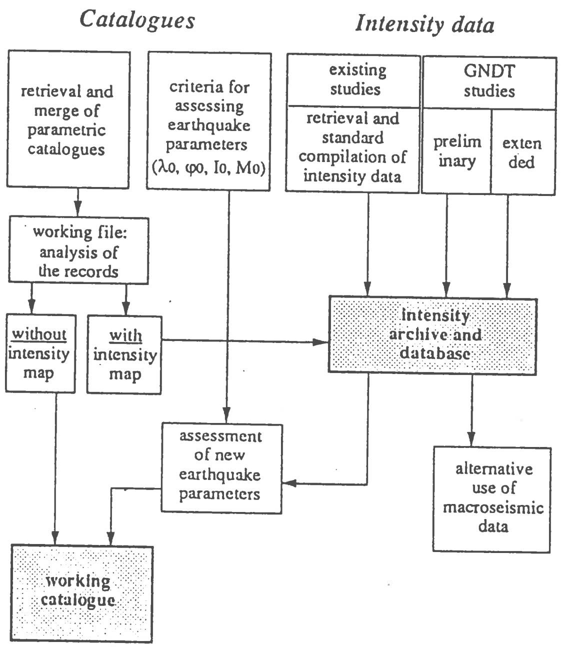

Fig. 1 - Flow-chart of the GNDT macroseismic project.

The general trend is today the design of databanks, able to store all the data produced by the research, at any level of elaboration. Nevertheless, as GNDT intends to update the seismic map of the building code of Italy, it has been decided to compile a preliminary working file, to serve as input for the seismic hazard evaluation (GNDT Hazard Assessment W.G., 1993). For the macroseismic part, the working file will contain records extracted from the most updated intensity point maps and records just retrieved from other parametric catalogues, when no intensity maps are available (Fig.1).

THE MACROSEISMIC PROJECT OF GNDT

The main goal of the macroseismic sector of the GNDT is to update and standardize the intensity database. For that purpose, all existing intensity point maps have been retrieved, standardized (that is, each datapoint has been referred to the same wording and coordinates), and put in some relationships with the records of the catalogue (Fig.2).

SEZIONE CATALOGHI									SEZIONE CARTE DI INTENSITA'									
N	Data	Ora	Lat	Lon	Ac	Cod	Bib	I_o	I_{max}	I_{min}	P_t	P_5	Area Epicentrale	Iso	Studio/Raccolta	Note	UR rif	D
157	1292	-	41 54	12 30	7	8	502	-					Roma					
	?1295	-							2/4						RM 2 n. p.			
158	1292	-	43 30	12 10	4	000	75	7					Monterchi					
	1292	-	43 34	12 08				8	8	8	1	1	Val Tiberina	N	Conversini et al., 1990	dubbio		P*
	-	-	-	-	-	-	-	-	-	-	-	-	-		Postpischl (ed.), 1990	da canc.		R*
									-	-	-	-	-		MC * (REG. TOS., GNDT)	da canc.		
159	1292	-	43 30	12 15	6	000	75	8					Val Bivano					
	-	-	-	-	-	-	-	-	-	-	-	-	-		Sga, 1987	dubbio		R*
	-	-	-	-	-	-	-	-	-	-	-	-	-		Postpischl (ed.), 1990	da canc.		R*
	-							-	-	-	-	-	-		MC * (REG. TOS., GNDT)	da canc.		
160	11/07/1293	-	43 55	10 55	4	000	75	9					Pistoia					
	11/07/1293	-						8/9	8/9	8/9	1	1	Pistoia		MC * (REG. TOS., GNDT)			
161	1293	-	40 45	14 30	4	000	75	8					Castellammare		MI 3 (AC)			
162	1294	-	41 30	14 30	5	000	75	8					Boiano		MI 3 (AC)			
163	1294	-	43 19	11 30	6	000	75	8					Siena					
	-	-	-	-	-			-	-	-	-	-	-		MC * (REG. TOS., GNDT)	da canc.	MC	

Fig. 2 - Section of the inventory of intensity point maps.

After inventorying the available intensity maps, it turned out that, out of 600 earthquakes with Io ≥ VII-VIII listed in the catalogue (Postpischl, 1985), nearly half had no intensity point map. On the contrary, for some events more than one investigation has been performed, leading to more than one intensity point maps, which are in principle difficult to compare.

It has been decided at that stage to define a simplified procedure which could allow to obtain, for the major earthquakes, a set of preliminary intensity point maps, produced by different teams of researchers according to standard procedures, in a relatively short time (Stucchi, 1991; Bellettati, 1993).

THE "ANALYSIS THROUGH THE COMPILATIONS"

The basic ideas which stand behind this procedures are that:

- most of the catalogue records have been derived by some of the main seismological compilations;
- most of the seismological compilation have investigated a considerable set of sources;
- to retrieve the entire set of sources used by the main compilations provides a larger potential of historical records which has not yet been investigated systematically;
- the compilations sources are quoted, therefore they are, in principle, easy to retrieve;
- in many cases this set of records, when interpreted carefully, improves the knowledge of the events to a large extent, before starting ad-hoc, detailed investigations.

For the Italian territory and neighbouring regions, some 65 main compilations were selected; each research unit (16) adopted some of them, according to the area and the time-window to be investigated. The compilations were then analyzed in correspondence of the earthquakes to be investigated, and all sources dealing with each earthquake were retrieved and plotted in a sort of stratigraphical family-tree (Stucchi and Albini, 1991). In some cases this procedure allowed to expand the source potential, just retrieving sources, in many cases nearest to the event, which had not been considered by the compilations.

It is to be stressed that this procedure, when applied carefully, may require the investigation of many more events than the starting ones: foreshocks, aftershocks, or simply events the timing and the location of which could have caused some overlapping of the historical records.

In such a way, about 300 major events have been processed.

SOME RESULTS

Considering both the already existing intensity point maps and those produced by GNDT according to the procedure described, it turns out that, in the time-window 1000-1690, about the 40% of the earthquakes have an intensity point map: the percentage rises to 50 for earthquakes with Io ≥ 6/7 MCS (Fig.3).

The distribution of this percentage per earthquakes, considered by class of Io, is shown in Fig. 3. Obviously, the percentage increases with increasing Imax, showing greater interest of investigators for such large events.

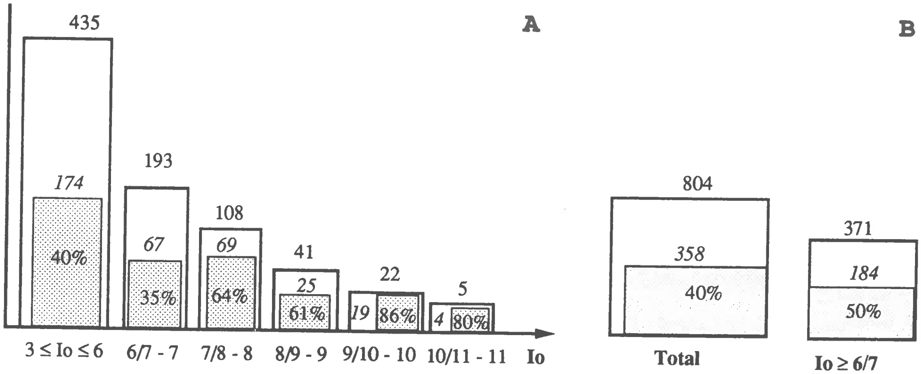

Fig. 3 - Percentage of earthquakes with intensity point maps: **A** per class of Io; **B** total and Io ≥ 6/7.

Fig. 4 shows the total number of intensity datapoints available for earthquakes of a definite class of Io, with respect to the number of earthquakes in the same class, and the correspondent rate. In general, it can be said that there are still many important (Io ≥ VII) earthquakes assessed by only one observation (datapoint); a few of them are located by important towns (Venezia, Pisa, Milano) where nearly no seismicity is reported after this time-window.

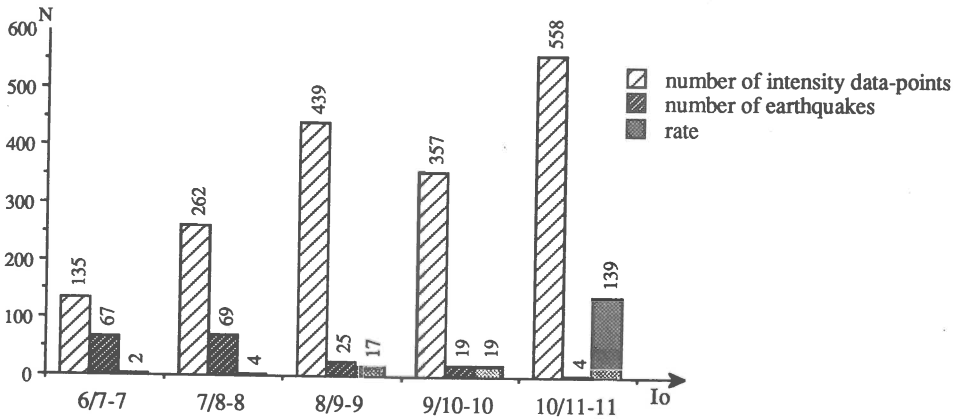

Fig. 4 - Availability of intensity data-points per class of Io (1000-1690)

A general trend of decrease of epicentral intensities is shown in Fig. 5. As a result, the number of earthquakes with epicentral intensities in the lower ranges (3-6) has increased. It is finally to be stressed that a considerable number of major earthquakes have been demonstrated to be fake quakes, as described by Camassi et al. (1993).

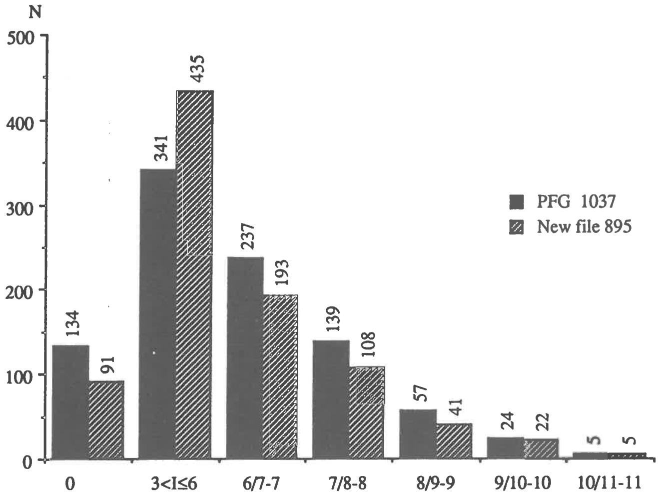

Fig. 5 - Comparison between PFG and New file epicentral intensities (1000-1690)

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LANDSLIDES INTERPRETED AS EARTHQUAKES IN EUROPEAN SEISMIC CATALOGUES

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Recent studies have pointed out the presence in European seismic catalogues of "false" earthquakes, mostly because of hasty or superficial readings of the sources. In particular, the apparent "similarity" in descriptions of landslides and earthquakes has lead to include in seismic catalogues simple landslides, as a consequence of their being interpreted as earthquakes (Albini and Vogt, 1992). Reasons of such misinterpretations are different. As a first approach a scheme has been proposed showing types of geological processes described by the sources versus a tentative typology of possible misinterpretation of phenomena, using some tens of examples concerning many European countries, gathered during years or researches in European libraries and archives. A review of some cases of misinterpreted events listed by catalogues have also been presented. The adopted methodology has been to go back to the original sources and carefully process them.

For instance, the famous 1618, Piuro (Northern Italy) landslide is still included in Swiss and Italian catalogues (Van Gils-Leydecker, 1991).This case can be seen as a double nonsense: the same event, a very well described landslide, with lot of contemporary and reliable sources, is located in two different places, Chiavenna and Sondrio (far 50 km each other); the date is different (August 25 and September 4) because expressed in two different styles by sources from different countries: translating from the Giulian calendar August 25 one obtains September 4.

The 1513 landslide in Biasca (near Bellinzona, Switzerland), which is also included both in the Italian and Swiss catalogues has turned out to be another well documented landslide (Albini et al., 1988). These examples lead to two simple statements: 1) the necessity of identify such misinterpretation inside the catalogues, specially by means of transfrontier research; 2) the importance of avoiding such mistakes in seismic catalogues used by engineers as well as seismologists: in fact the presence of non seismic event in seismic catalogues can signify a misleading knowledge of the seismicity of an area.

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A VERY LARGE EARTHQUAKE OF 1880 IN THE ATLANTIC OCEAN, UNTIL NOW UNKNOWN. SEISMOLOGICAL AND METHODOLOGICAL CONSIDERATIONS

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INTRODUCTION

During the last years, in my researches on historical seismicity of the XVIII and XIX centuries, I followed two different methodologies: a) investigating already known earthquakes, the research is concentrated on different kind of sources, but especially coeval periodical press: I call this methodology "intensive", because its goal is to "increase" the reliability of the parameters given by the catalogues and eventually to correct and improve data which have been misinterpreted in the existing catalogues; b) on the other side, a systematic reading of the periodical press has the scope to gather information on new earthquakes, that is until known not reported by the catalogues. This method, slow and painstaking, has given interesting results (see Albini and Rodriguez de la Torre, 1993); I call it "extensive", because it permits to find information on unknown earthquakes: such events are for the most part of low intensity, but sometimes major earthquakes have been found, until now not reported by catalogues.

THE LARGE EARTHQUAKE OF 21 OCTOBER 1880

Systematic reading of the periodical press has permitted to identify hundreds of "unknown" events occurred in the Iberian Peninsula, especially in the XIX century. In the previous ESC General Assembly (Barcelona, 17-22 September 1990), results were given on the revision of the Iberian catalogue (Portugal and Spain) for the time-window 1851-1900 (Rodriguez de la Torre, 1990):

- parameters given by the catalogues were maintained only for 117 out of 515 earthquake considered;
- concerning the other 398 events, one or more changes were proposed: revaluation of intensity; change of localization; change of date and time; also, some of them were demonstrated to be fake quakes or duplications;
- moreover, information on 1693 unknown events were gathered.

The 21 October 1880 event, occurred at 6.41 a.m. (Lisbon time) is one the major earthquakes discovered; it can be considered an important one may be not for its intensity on the main land (grade VI MMI), but for the extension of the involved area and the hypothesis of high magnitude that is formulated in this paper.

The research carried out permitted to gather information from 20 newspapers printed in four localities and from 7 scientific journals, printed in five different localities. Table 1 shows titles and dates of the journals which give information on the earthquake.

Reading the texts, one learns that: - the earthquake was felt in all the western part of the Iberian Peninsula (about 300.000 square kilometres); - in the most part of Portugal the estimated intensity is grade VI MMI, while the intensity decreases in the central Iberian "meseta" to grade III in Madrid; - the earthquake was strongly felt in the Guadalquivir valley (Andalucía) as far as Linares (grade V MMI). The total number of localities for which data permits to hypothesize an intensity is 34.

N E W S P A P E R S :

LISBOA: * Jornal do Commercio (22nd Oct. 1880, p. 2; 23rd, pp. 1, 2 and 3; 26th, p. 2; 27th, p. 2; 30th, p. 2; 31th, p. 1.
* O Progresso (23rd Oct. 1880, pp. 1, 2 and 3; 24th, p. 1).

LUGO: * Diario de Lugo (24th Oct. 1880, p. 1).

MADRID: * El Constitucional Dinástico (26th Oct. 1880, p. 3).
* El Correo (22nd Oct. 1880, pp 2 and 3).
* El Diario Español (21st Oct. 1880, p. 3; 22nd, pp. 2 and 3).
* El Fénix (22nd Oct. 1880, pp. 2 and 3; 26th, p. 3; 28th; p. 3).
* El Globo (22nd Oct. 1880, p. 3; 23rd, p. 3).
* El Imparcial (22nd Oct. 1880; pp. 3 and 4).
* El Liberal (22nd Oct. 1880, pp 2 and 3; 23rd, p. 3).
* El Popular (22nd Oct., pp. 1 and 2; 23th, p. 2).
* El Siglo Futuro (22nd Oct. 1880; pp. 3 and 4).
* El Tiempo (22nd Oct. 1880; p. 2).
* Gaceta Universal (22nd Oct. 1881, p. 2; 23rd, p. 2).
* La Correspondencia de España (21st Oct. 1880; pp. 3 and 4; 23rd, p. 3; 26th, p. 2).
* La Correspondencia Ilustrada (23rd Oct. 1880, p. 3; 25th, p. 3).
* La Epoca (22nd Oct. 1880, p. 4).
* La Fe (22nd Oct. 1880; p. 3).
* La Iberia (22nd Oct. 1880, p. 3).

VIGO: * El Faro de Vigo (21st Oct. 1880, p. 3; 22nd, p. 2; 23th, p. 1).

S C I E N T I F I C S R E V I E W S :

BARCELONA: * Crónica Científica (25th Nov. 1880, p. 542).

MADRID: * Boletín de la Sociedad Geográfica (1880, pp. 370-371).
* Gaceta Agrícola del Ministerio de Fomento (1880, pp. 377-379).
* Gaceta de Madrid (22nd Oct. 1880, p. 276: "Metheorological Observations").

LONDON: * Nature (29th Oct. 1880, p. 615).

PARIS: * La Nature (30th Oct. 1880, p. 351)

ROMA: * Bullettino del Vulcanismo Italiano (1882, p. 64).

Tab. 1 - Periodical press and scientific reviews with information about the 21 October 1880 earthquake.

Using all the available data, the following parameters are here hypothesized:

- time: 21st October 1880, 06.41 a.m. (Lisbon time);
- perceptibility area: 300.000 square kilometres;
- Imax = grade VI MMI (about 40.000 square kilometres);
- epicenter: coordinates 38° N - 18°W, in the Atlantic Ocean (?)
- magnitude: 7.5 (?).

METHODOLOGICAL CONSIDERATIONS

Management and interpretation, in terms of reliability, of hemerographical sources have been discussed in a previous contribution (Rodriguez de la Torre, 1989). The point to be evidenced in this case is that the methodology of analytic reading of the periodical press, in order to "discover" new earthquakes, seems to be particularly useful, since it permitted to get knowledge of a strong earthquake, not so far back in time, and until now unknown.

Moreover, this can be a further confirmation of the fact that not all major earthquakes of the past centuries have "already" been inserted in the available seismic catalogues.

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PERSEUS PROJECT: A GIS FOR HISTORICAL SEISMOLOGY ORGANISATION AND FIRST RESULTS

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INTRODUCTION

In Italy the seismic activity is various, widespread and, for more than a thousand years, well documented. Furthermore, a greater depth of study of the extent of seismic threat and the various details of terrain favours our overall understanding of the characteristics of the seismic activity.
This character, always and in any event territorial, does not, however, find a direct parallel in the present arrangement of the various existing catalogues, where earthquakes are still shown in the synthetic form of records of data.
This viewpoint does not change even when this logic would seem to be overtaken with the introduction of the idea of data banks that, in their hierarchical arrangement of information, reflect a model of presentation of data, that can be described as 'catalogue-centric'.

THE SEISMIC CATALOGUES AS A *PROCUSTES'S BED* ?

To illustrate the limits of the existing seismic catalogues we can draw on an image from the classical myths. The story goes that on a road of Athens there lived a famous but dangerous host who was only too willing to offer lodgings for the night to unfortunate travellers. Little did these travellers realise, however, that the size of the bed determined whether their limbs would be lopped off or stretched out until the length of their bodies coincided with that of the bed. This story seems to us to be an apt illustration of the fate of historical seismic data in seismic catalogues.
As a result, on the one hand, important pieces of contextual information concerning the characteristics of the affected area are 'lopped off', when they could have shown the impact of that particular earthquake in the inhabited area; on the other hand, some geographical and chronological indications applicable to a single locality are 'stretched out', thus altering the original character of the information.The organisation of the data bank set up by the PERSEUS project (**P**roject **E**laboration of historical **R**esearches **S**eismic **E**vents on **U**nified informative **S**ystem.) creates in a progressive way a dynamic model of the area, related to the different seismic scenarios . In this way the problem of the evaluation of the degree of severity is opened up to

more precise considerations, reducing to a minimum the interference of 'subjective' or 'one-sided' interpretations that have so often, and rightly been criticised in this area.
The existing links between the natural phenomenon of the earthquake and the more general seismic scenarios are clarified by means of a system that allows the use of these data that are available today thanks to historical research that could not be used if the Catalogue was the only point of arrival. The data used to create a model of the historical context refer not only to the demographic dimensions of the sites concerned, the prevailing character of the buildings, the type of damages caused and the territorial distribution of the effects, but also to the workings of the administration and the chief elements of the local economy and government.

THE PHILOSOPHY OF PERSEUS

In the light of these previous remarks it will be clear that this project PERSEUS has set itself the objective of using the most advanced historical research to its fullest extent, encouraging, with the new integrated data, the contribution of scientists in many different fields: from seismologists to seismic engineers to actual historians. To do this, it has been necessary to insert large quantities of data relating to demography, economic and administrative history. To make it possible to use these new 'historical seismic images' a logical scheme has been set up where the complete range of information is available.
Geographical information systems (GIS) already in use for a decade in some areas of management, have proved to be extremely effective tools in area management and planning.
In a GIS the model of a particular territory, displayed on a colour monitor, is the work environment itself - that is, the support of the retrieval system of the data-bank that lies behind the map - and not a way of representing the various thematic areas as happens today in the passage of the data selected by the catalogue for the various 'plotted' maps.
With PERSEUS it is possible to georeference all present and historical, numerical, objective or descriptive information in a representation of the area. PERSEUS has been developed with the SYSTEM 9 language, one of the most advanced types of software for GIS presently available. SYSTEM 9 is in fact a dual system. On the 'lower' level is a complete Data Base Management System (DBMS EMPRESS) of a cross-referencing type.

This level is responsible for the construction and physical management of the data bases necessary for the application to PERSEUS. On the upper level is the actual SYSTEM 9. This system has the task of constructing the logical, and particularly the topological, links between the base elements making up the complex objects. SYSTEM 9 operates on entities called 'PROJECTS', which are simply a series of data bases containing all the information relative to a particular area. In view of the supranational character both of seismicity and of the workings of the earth's crust that generate it and given the operating area of the MEDNET network, PERSEUS covers the whole of the Mediterranean basin.

At the topological level PERSEUS operates both on single objects, such as buildings or isoseismic areas and on complex objects, such as inhabited areas (a collection of individual buildings) or maps of isoseismic areas, where there is an obvious hierarchical relationship between the various types of area.

PERSEUS deals with present-day and historical areas, inhabited localities, urban maps, epicentres, altimetric and bathymetric contour lines, orography etc.

The information of a descriptive or numerical type is that related to the bibliographical data of the collected historical evidence, to the historico-critical comments relating to historical earthquakes already studied, to the integral texts of sources etc.

The availability of the original texts, transcribed and memorised in a data bank like PERSEUS, offers the potential for large amounts of information that with the usual retrieval systems can only be used with difficulty. One of the most frequently used systems is that of the pre-defined key-word. This system is not, in our opinion, capable of exploiting to the full the multidisciplinary nature of a GIS like PERSEUS.

The use of key-words, by its very nature, has the effect of imposing a rigid application of the categories decided by the list of key-words. Furthermore, classification by key-word is functional to the type of use that produced the list of key-words. In order to overcome this limitation and make the PERSEUS retrieval system more flexible and open, a system has been provided for the total indexing of the words in the memorised texts. In this way the PERSEUS is able to carry out in full its function of integrating data, both for scientific objectives and for the dissemination of information.

PERSEUS started in 1991. In the next months will be accomplished the first part of the work. It will include a complete elaboration, according to the criteria mentioned above, of the data concerning 345 highly intensive seismic events. These materials are comprehensive of all seismic disasters in Italy from antiquity to twentieth century, known by the seismological literature It is worthwhile mentioning that several events have concerned, at different levels, large areas which could cover thousands of square kilometrs.

After this first part of work, the evidence already passed into memory, with direct access to the bank of data, will be composed of over ten thausand sources. These data will cover about ten thausand informations on seismic history.

In a further step of work, it will be possible to apply PERSEUS to a wider range of cases, covering also the less intensive events.

FORESHOCK STATISTICS IN THE ITALIAN SEISMICITY

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INTRODUCTION

The Italian national seismic catalog contains more than 15,000 epicenters collected by ING (Istituto Nazionale di Geofisica Roma) in the period from January 1975 to December 1991, by means of the continuous operation of the Italian national seismic network. We started our analysis with a recognition of the space-time distribution of the seismic events contained in the ING catalog, with special care to defining their clustering properties. The results of this analysis allowed a tentative subdivision of the territory in different areas characterized by fairly homogeneous behavior (Alessandrini et al., 1990). Some areas exhibit frequent activity but never exceeding moderate magnitude values, while others regions are characterized by a scarcity of moderate events combined with the capability of occasional large earthquakes. In particular, the boundaries shown in Figure 1 (Central Apennines) coincide with those drawn by Basili et al. (1990) in their seismotectonic zonation of the Italian territory, except for the deletion of a small part at the south that we judged as characterized by a lower rate of seismicity. It was noted that in this area sequences of the swarm and foreshocks-aftershocks types are clearly predominant. This empirical regionalization is useful for selecting the areas in which further investigations about statistical properties of foreshocks-mainshock sequences are likely to give more reliable results. This study focuses on the foreshocks of earthquake sequences recorded by the ING in the last fifteen years.

FORESHOCKS AS EARTHQUAKE PRECURSORS

With the purpose of analysing short range space-time interactions among earthquakes, we set up a simple algorithm for finding out foreshocks. We consider as foreshocks the events exceeding a given threshold magnitude M_f, with the conditions that they follow a period of quiescence and come before a mainshock occurring within a given distance range. These conditions are given as follows: 1. No other event occurs for a period of time T_1 previously to the i-th event, with magnitude exceeding or equal to M_i within a distance R_1 from its epicenter (x_i, y_i). 2. Another event with magnitude greater than M_i and greater or equal to M_m (magnitude threshold for main shocks) occurs within a period of time T_2 after the i-th event within a distance R_2 from its epicenter (x_i, y_i).

Condition 1 defines all the potential foreshocks, i.e. the events that possibly could start a seismic sequence containing at least one earthquake of magnitude greater than M_m. The events that satisfy both conditions 1 and 2 are defined real foreshocks. Those that satisfy condition 1, but not condition 2 are called single shocks (or mainshocks if their magnitude M_i exceeds M_m). Speaking about foreshocks as earthquake precursors (anomalies), we call the occurrence of real foreshocks as successful predictions, the occurrence of potential foreshocks without mainshocks as false alarms, and the occurrence of mainshocks without foreshocks as missed alarms (unpredicted earthquakes). Following the definitions of Reasenberg and Matthews (1988), in our case the 'validity' is computed by the ratio between the number of real foreshocks and the total number of possible foreshocks, while the 'reliability' is computed by the ratio between the number of mainshocks preceded by foreshocks and the total number of mainshocks.

AN APPLICATION TO CENTRAL ITALY

A computer routine was written for assessing the validity of the predictions based on foreshocks, on the basis of a given data set and for a given choice of the six parameters M_f, M_m, R_1, T_1, R_2, T_2. This program, after having scanned all the catalog of events by means of the above mentioned algorithm for the objective definition of foreshocks, provides the number of successful predictions (N_s), the total number of predictions (N_f) and the total number of mainshocks to be predicted (N_m). Note that, if more than one foreshock for the same mainshock is detected, the program increments the counter of successful predictions (N_s) by one unit only.

The program was applied to the data set obtained selecting from the ING (1975-1991) catalog all the events with magnitude equal or larger than 2.5 the epicenters of which fell within the boundaries of Figure 1 (Central Apennines). The total number of events included in this data set is 2671.

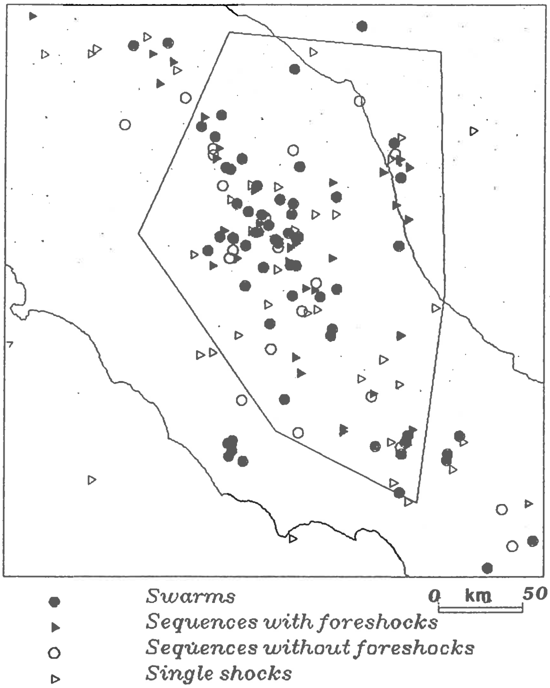

Fig. 1 - Geographic distribution of the seismicity recorded in the Central Apennines area by the seismological network of the Istituto Nazionale di Geofisica between 1975 and 1991. The different kinds of seismic series are reported according the definition given by Alessandrini et al. (1990).

In order to explore the influence of the different parameters on the validity and reliability of the predictions, we had to fix some of them and leave some others variable.

As a first test, we proceeded in the following way:

- Assigning arbitrary values to the magnitude parameters for the foreshock threshold (M_f) and mainshock threshold (M_m)
- Letting the couple R_2 and T_2 change on an assigned grid of values
- For each of the previous choices, letting the program find out the best value of the success rate (validity) in a given range of the couple of parameters R_1 and T_1.

Table 1 shows the limits and the steps of variation imposed for all the parameters.

TABLE 1
RANGE OF VARIATION FOR THE PARAMETERS USED IN THE FIRST SEARCH FOR OPTIMAL DEFINITION OF FORESHOCKS

Parameter	minimum	maximum	step
M_f	3.0	3.0	0.0
M_m	4.0	4.0	0.0
R_1 (Km)	10	150	10
T_1 (days)	5	100	5
R_2 (Km)	5	70	5
T_2 (days)	0.5	10	0.5

In Figure 2 the optimal values obtained for the success rate versus the couple of parameters R_2 and T_2 are reported. It shows how the success rate increases as R_2 and T_2 increase. It is also clear that the rate of this increase is large at small values of R_2 and T_2 and becomes smaller as they become larger. This result, meaning that mainshocks preferably occur at short space and time distance from their foreshocks, is in general agreement with what observed by Jones (1985) for California. Looking at Figures 2, it appears clear that there is a wide range of possibilities in front of one that wants to assess the convenience of issuing an alarm on a more or less wide space-time area. The information obtained by the analysis of the past seismicity, certainly provides a guidance to decision makers concerned with such problems. In our second test we wanted to put in evidence the role of the two parameters R_1 and T_1 on the optimization of the success rate. Through these parameters the skill of the Geophysicists, on the basis of the information obtained from the past experience, can contribute to decide in optimal way sites and times for issuing warnings. To do it, we fixed the couple of parameters R_2 and T_2 at such values that the success rate inferred from Figure 2 resulted about 10 % . That is the case, for instance of R_2 = 30km and T_2 = 2 days. We let change in the program R_1 and T_1 by small steps on a dense grid as shown in Table 2.

TABLE 2
RANGE OF VARIATION FOR THE PARAMETERS USED IN THE SECOND SEARCH FOR OPTIMAL DEFINITION OF FORESHOCKS

Parameter	minimum	maximum	step
M_f	2.5	3.5	0.5
M_m	4.0	4.0	0.0
R_1 (Km)	5	150	0.25
T_1 (days)	5	100	0.25
R_2 (Km)	30	30	0
T_2 (days)	2	2	0

The program was designed to memorize, among the numerous cases examined, the minimum and maximum number of potential foreshocks that were necessary to obtain any possible number of successes. The results for $M_f = 3.0$ are reported in Figure 3. They show how many times we should have to issue a warning to get a given number of mainshocks and how much this number changes in dependence of the best or the worst choice for the definition of foreshocks. For example, for getting ten mainshocks of magnitude 4.0, the different definitions of possible foreshocks lead to the consequence of issuing from a minimum of 194 to a maximum of 318 warnings. The largest success rate, as shown also in Figure 2, is about 0.095 and comes from 6 successes out of 23 mainshocks and 63 possible foreshocks. The correspondent values of R_1 and T_1 are 140 km and 80 days respectively.

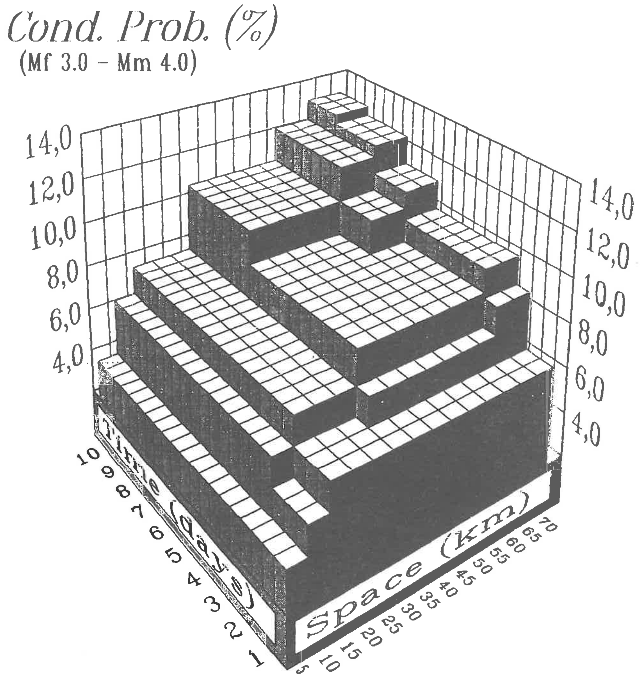

Fig. 2 - Three-dimensional histogram of the success rate (%) in predicting events of magnitude 4.0 and larger by means of potential foreshocks of magnitude 3.0 and larger, versus the distance and delay time between foreshock and mainshock. The success rate is optimized against the parameters defining potential foreshocks.

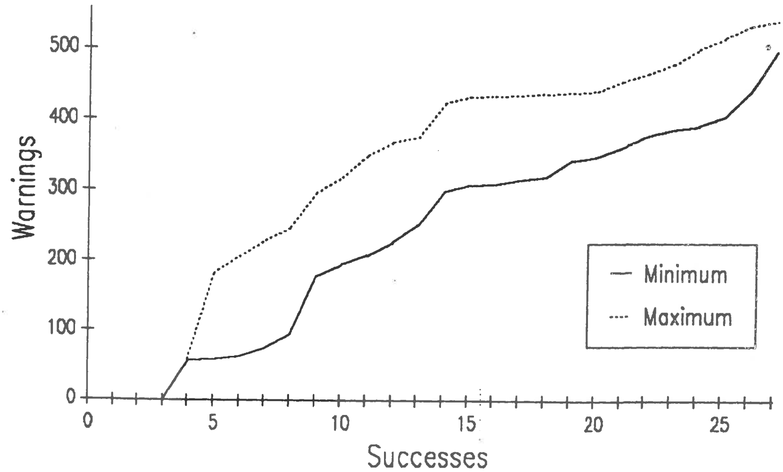

Fig. 3 - Minimum and maximum number of possible foreshocks of magnitude 3.0 and larger necessary to predict mainshocks of magnitude 4.0 and larger, versus the number of successful predictions. The two extreme values are computed according to different choices of the parameters defining possible foreshocks.

CONCLUSIONS

The results of the analysis of foreshock properties in an area of about $32,000 km^2$ in Central Italy show that there is a significant tendency of moderate shocks to be followed at short distance and in short time by larger shocks.

Aki (1981) defined the probability gain, in connection with a generic kind of earthquake precursor, as the value of the validity divided by the average rate of occurrence.

The application of our method to the seismicity recorded in the Central Apennines (Fig. 1) would lead, with the choice of parameters shown in Table 2, to predict 6 out of 23 mainshocks of $M \geq 4.0$, issuing in total 63 alarms lasting two days in areas of 30 km radius. The average rate of occurrence of at least one of these 23 mainshocks in an area of such dimensions during the same time period is estimated considering the total area of the territory (about $32,000 km^2$) and the total time spanned by the catalog (6,209 days). The spatial distribution of the seismicity in this area (Fig. 1) doesn't show any particular concentration suggesting the existence of zones characterized by higher probability of occurrence. The computation leads to an average rate of $6.5 * 10^{-4}$. Comparing it with the success rate of 0.095, it can be inferred that this kind of precursors (the occurrence of an event of magnitude exceeding 3.0 after at least 80 days of quiescence in an area of 140 km radius) causes a gain of about a factor of 150 in the probability of occurrence of larger events of magnitude exceeding 4.0 during the following 48 hours in the specified area of 30 km radius.

These results can be extended to other seismic areas using the same procedures. They can also be improved as more accurate and more complete data become available by means of modern seismological networks. Moreover, the success rate would become higher applying more sophisticated criteria in order to separate real foreshocks from the events just belonging to the background seismicity.

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STATISTICAL MODELLING OF THE INTERMEDIATE DEPTH SEISMICITY OF VRANCEA, ROMANIA

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INTRODUCTION

The present paper attempts to model the seismic activity in the intermediate depth focal zone of Vrancea, Romania, in order to obtain characteristic space and time seismicity patterns of this region.

The analysis is based on Matsumura's (1984) parametrization, which is related to the interactions in the earthquake sequences and is derived from the Weibull distribution.

This study improves the previous researches (Radu, Ardeleanu, 1989; Ardeleanu, Şmalbergher, 1992), by using a homogeneous, accurate and considerably increased data set, which allows a detailed three-dimensional analysis of the zone.

DATA

A set of 1377 earthquakes with depth $60 \le h \le 200$ km and magnitude threshold $M_L = 2.5$, which occurred in the period 1980-1989, is used in the analysis.

The hypocenters are located on the basis of the records of the Romanian seismic network (18 telemetered stations and 27 local stations), using Herrin - Randall tables, with station time corrections.

Only the readings with absolute arrival - time residuals less than 1.5 s for P waves and 2.0 s for S waves are selected, and the events with less than 5 observations (P and S arrival times) are eliminated.

Epicenters are accurate to about $\pm 0.1^o$ and depths to about $\pm$ 10 km.

Magnitudes are determined from the duration of earthquake coda (Lee et al., 1972).

We note the occurrence of a major earthquake with magnitude $M_S = 7.0$ on August 30, 1986 ($\phi = 45.50^oN$, $\lambda = 26.47^oE$, h = 141 km). Its aftershock sequence (~ 200 events with $M_L \ge 2.5$) lasted about two months.

SEISMICITY PATTERN

Briefly, the method proposed by Matsumura consists in characterizing the seismicity patterns in space and time by one parameter.

The method is based on the analysis of point patterns distributed in a two-dimensional space, considering the distribution of distances Δ between the nearest adjacent point pairs. The horizontal axis is regarded as the time and the vertical one as distance. If the earthquakes occur independently in both space and time, the point density μ is constant. If there are some interactions between points they can be modelled by introducing a Δ dependence for μ.

Assuming the form:

$$\mu = \mu_o \Delta^{p-2} \qquad (1)$$

Matsumura derived the probability density function for the distance Δ:

$$f(\Delta) = \pi\mu_o\Delta^{p-1}\exp(-\pi\mu_o\Delta^p/p) \qquad (p > 0) \qquad (2)$$

In that case $f(\Delta)$ is a Weibull distribution.

The form of μ implies two types of interactions: attractive interactions for $p < 2$ and repulsive interactions for $p > 2$. The corresponding patterns are characterized as clustered patterns for $p < 2$ and regular (periodical in time) patterns for $p > 2$. The value $p = 2$ represents a random pattern.

The indicator ν introduced to measure the randomness of the point distribution is defined by the relation:

$$\nu = (\overline{\Delta})^2 / \overline{\Delta^2} \qquad (3)$$

The mean and the mean - square of the observed distances Δ are equaled to the first and the second moments of the probability density function of equation (2) respectively and the theoretical expression of ν is obtained :

$$\nu = [\Gamma(1/p + 1)]^2 / \Gamma(2/p + 1) \qquad (4)$$

where Γ is gamma function.

According to (4) the two-dimensional point patterns are classified as clustered patterns for ν values in the range 0 to $\pi/4$ and regular (periodical in time) patterns for ν values in the range $\pi/4$ to 1. The border value $\nu = \pi/4$ corresponds to completely random patterns.

To analyse our seismicity data by the parameter ν, the region: $45.2 \le \phi \le 46.0^{o}$N, $26.0 \le \lambda \le 27.0^{o}$E and $60 \le h \le 160$ km is divided in three - dimensional blocks having length 0.8 latitude degrees, width 0.2 longitude degrees and thickness 20 km. Neighbouring blocks are shifted by 0.1 degrees in longitude and 10 km in depth. The spatial distribution of the hypocenters is regarded as one-dimensional along the N-S direction.

For each block a two-dimensional point pattern is obtained. The time window is 9 years. Different blocks have a different point number, but a minimum of 50 data points is required to evaluate ν.

The reference value ν_{random} is corrected taking into account the nonuniformity of the density on the distance axis (Matsumura, 1984):

$$\nu_{random} = \pi/4 \left(\overline{\sqrt{\mu}} \right)^2 / \overline{\mu} \qquad (5)$$

where $\overline{\mu}$ is a mean of the density on the distance axis.

The analysis is repeated considering E-W orientated three-dimensional blocks, with length of 1 longitude degree, width of 0.2 latitude degrees and thickness of 20 km. Neighbouring blocks are shifted by 0.1 degrees in latitude and 10 km in depth; the space distribution of earthquakes is treated as one-dimensional along the E-W direction.

The seismicity pattern of the whole zone is obtained by linking all individual results.

Fig. 1 shows a tomography of the region under investigation, taking into account all the events which occurred during the period 1980 - 1989. In the white areas, the parameter is not evaluated due to the lack of sufficient data. For the clustered zones the threshold level of the parameter is set at 85% of ν_{random} and for the highly clustered ones at 80% of ν_{random}.

By eliminating the aftershocks of the major event of August 30, 1986, the seismicity pattern that characterizes the whole region is the random pattern.

The clustered and highly clustered patterns of Fig. 1 are determinated by the aftershocks of the strong earthquake of 1986 and they evidence the space - time distribution of the aftershock sequence in the depth range 120 to 160 km.

Into this seismogenic volume: $45.3 \le \phi \le 45.7^{o}$N, $26.2 \le \lambda \le 26.7^{o}$E, $120 \le h \le 160$ km, a special attention is paid to detect significant anomalies of the two-dimensional seismicity patterns, preceding the major earthquake. The analysis is carried out for three-dimensional blocks orientated N-S and E-W and time window of 6 years (October 1980 - August 1986). For the blocks containing a sufficient number of hypocenters, the time variation of the parameter ν is also studied, using moving time windows of 50 events with the step of 5 events. The fluctuations of ν values relative to ν_{random} are unsignificant in all cases, less than ± 10% of the reference value.

Since the magnitude threshold of the earthquakes could influence the seismicity patterns, the previous analysis is repeated taking magnitude thresholds of 3.0 and 3.5. Unfortunately, the data do not allow to choose magnitude thresholds in the range of moderate earthquakes. The results do not point out changes of the seismicity pattern, preceding or following the occurrence of the major earthquake of August 1986, excepting the clustering due to its aftershock sequence.

CONCLUSIONS

On the basis of a homogeneous and complete set of 1377 Vrancea earthquakes, with depth $60 \le h \le 200$ km and magnitude $M_L \ge 2.5$, which occurred in the period 1980 - 1989, a statistical modelling is obtained, using the parametrization introduced by Matsumura (1984).

In the previous studies, the seismogenic zone was regarded as a whole (Radu, Ardeleanu, 1989) or it was divided in 40 km depth layers (Ardeleanu, Şmalbergher, 1992), in order to analyse the time variation of the parameter ν, which was evaluated for moving time windows of 50 events.

The present paper performs a detailed investigation, by using three - dimensional blocks. The time window of 9 years allows a more accurate evaluation of the parameter ν (the number of data points in the two-dimensional patterns varying from 50 to 338).

The conclusions of this study are in good agreement with the results of the previous researches.

The seismicity pattern, characterizing the whole Vrancea intermediate depth focal zone, is the random pattern.

The increase of the magnitude threshold (but still remaining in the range of weak earthquakes) does not influence the seismicity pattern.

The detailed study of the aftershock zone of the August 30, 1986 earthquake, carried out by dividing it in three-dimensional blocks and using different time windows, does not point out significant changes of the seismicity pattern preceding that major event.

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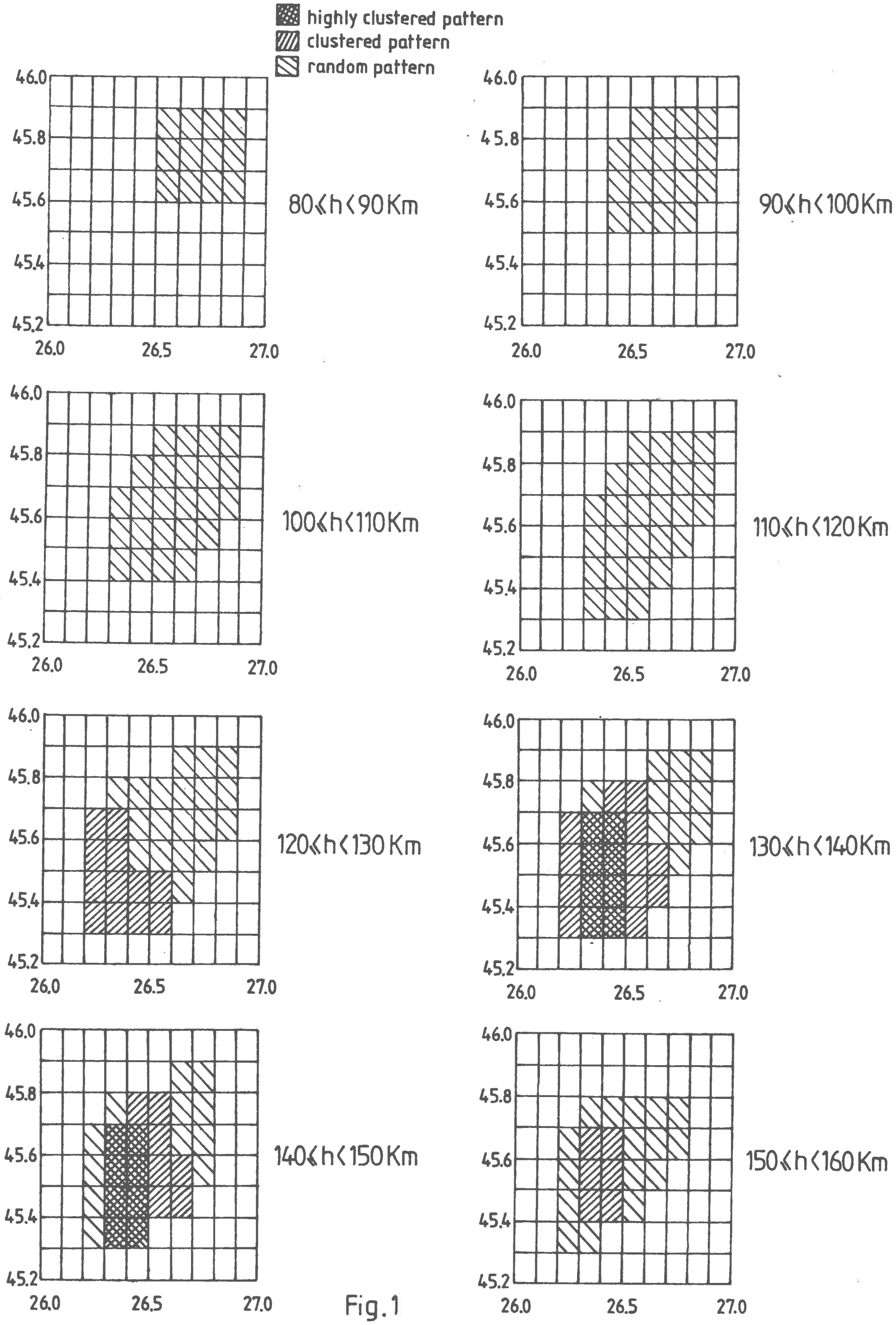

highly clustered pattern
clustered pattern
random pattern
80≤h<90Km
90≤h<100Km
100≤h<110Km
110≤h<120Km
120≤h<130Km
130≤h<140Km
140≤h<150Km
150≤h<160Km
46.0
45.8
45.6
45.4
45.2
26.0
26.5
27.0

Fig. 1

SHAKEBILITY ASSESSMENT IN THE GULF OF CORINTH AND SURROUNDING REGION USING DIFFERENT MODELS

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INTRODUCTION

The gulf of Corinth and surrounding region is one of the most seismically and tectonically active areas in Greece (Delibasis, 1968, 1981; Leydecker, 1975; Drakopoulos et al., 1978). Many significant destructive earthquakes have been reported in the ancient times (see e. g. the complete destruction of Eliki in 373 B.C. and the severe damage to Aigio near Patras in 1748), but also in the present century (possible destruction of the wall in Mycenes, catastrophe of the city of Corinth in 1928, etc.). The general tectonic evolution of the area can be divided into two stages: (1) the Alpine stage, characterized by horizontal compression causing thrusting and folding with a general N - S to NNW - SSE trend during Eocene to early Miocene times, and (2) the post-Alpine stage, characterized mainly by vertical movements along normal gravity faults of the post-Miocene age. Fig. 1 presents the main tectonic features of the broader region. The E - W trending faults of the gulf of Corinth are seismically very active in contrast to the NW - SE faults of southeastern Peloponnesus which are relatively inactive. This difference is found all over the southern Aegean, with a central segment characterized by NW - SE major tectonic trend and very low seismicity between the two other segments characterized by E - W to ENE - WSW neotectonic trends and high seismicity (Mariolakos et al., 1985). The reactivation of faults already existing in the gulf of Corinth has ben pointed out by surface crack observations associated with the 1928 and 1981 major earthquakes. However this has also been separately associated with important crustal deformations, as revealed by repeated leveling data (Mariolakos and Stiros, 1986).

SEISMIC HAZARD ASSESSMENT

The assessment of the regional seismic hazard is obtained using the hypotheses of (1) large generalized seismogenic zones containing active faulting, and (2) tectonic lines supported by seismicity evidence. Two computer codes are applied and the differences in the probabilistic calculations of seismic hazard discussed. The FRISK code (McGuire, 1978) has the most important advantage of the recognition of the rupture length as the most significant parameter in seismic hazard assessment. Probabilistic uncertainties in the location of the rupture zone on the fault, in the maximum possible magnitude and in the expected ground motion are accounted for explicity. The SEISRISK code (Bender and Perkins, 1987) is based on the Cornell (1968) approach, that is the seismicity is considered uniformely distributed over the seismogenic zone, an exponential distribution is accounted for the earthquake magnitude and the recurrence times are modeled by a Poisson process. Two seismogenic zones and two main faults are introduced as seismically active (SZ1 - F1 and SZ2 - F2 in Fig. 2a). The events corresponding to these sources are mainly superficial, with an average depth of 10 km. A minimum magnitude 2.5 is associated with each fault, while the maximum expected magnitudes are chosen 6.6 and 6.8, and 5.5 and 5.8 for F1 and F2, respectively, with probabilities 70% and 30%.

The last 87 years are used to estimate the annual seismicity rates and b-values required as input. Two different approaches have been attempted considering an average and individual seismicity rates, leading to slight differences in the obtained hazard maps. The attenuation formulae for Greek earthquakes proposed by Makropoulos (1978), Papaioannou (1984), and Theodulitis (1991) are used in the estimation of maximum ground motion. Finally, the Kiratzi et al. (1985) magnitude/rupture length relationship is introduced in the analysis.

RESULTS

The output of the present analysis is presented in terms of maximum horizontal peak ground acceleration (PGA, in Gal) expected not to be exceeded at 37% probability in 100 years (Fig. 2). The highest values, larger than 300 Gal, are found in the central part of the gulf of Corinth, with a maximum value of 366 Gal in its western section, when applying the Thodulitis (1991) formula (Fig. 2f). Higher accelerations and slightly different shapes in the

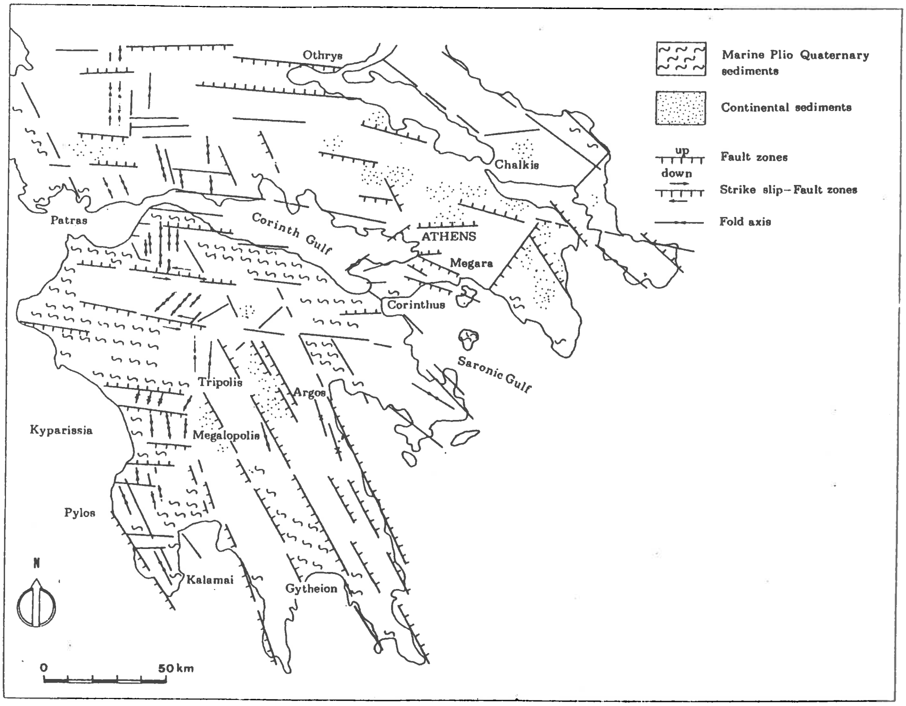

Fig. 1 - Tectonic map of the Peloponnesus (from Mariolakos et al., 1985).

isolines are obtained using the other mentioned attenuation relations, emphasizing the importance of the derivation of regional/local attenuation relationships.

The significance of the estimation of seismicity parameters is pointed out using an average rate and individual seismicity rates in the input data set (Figs.2c and 2d) of F1 and F2 faults. This test is motivated by the fact that around the F2 fault the present-day

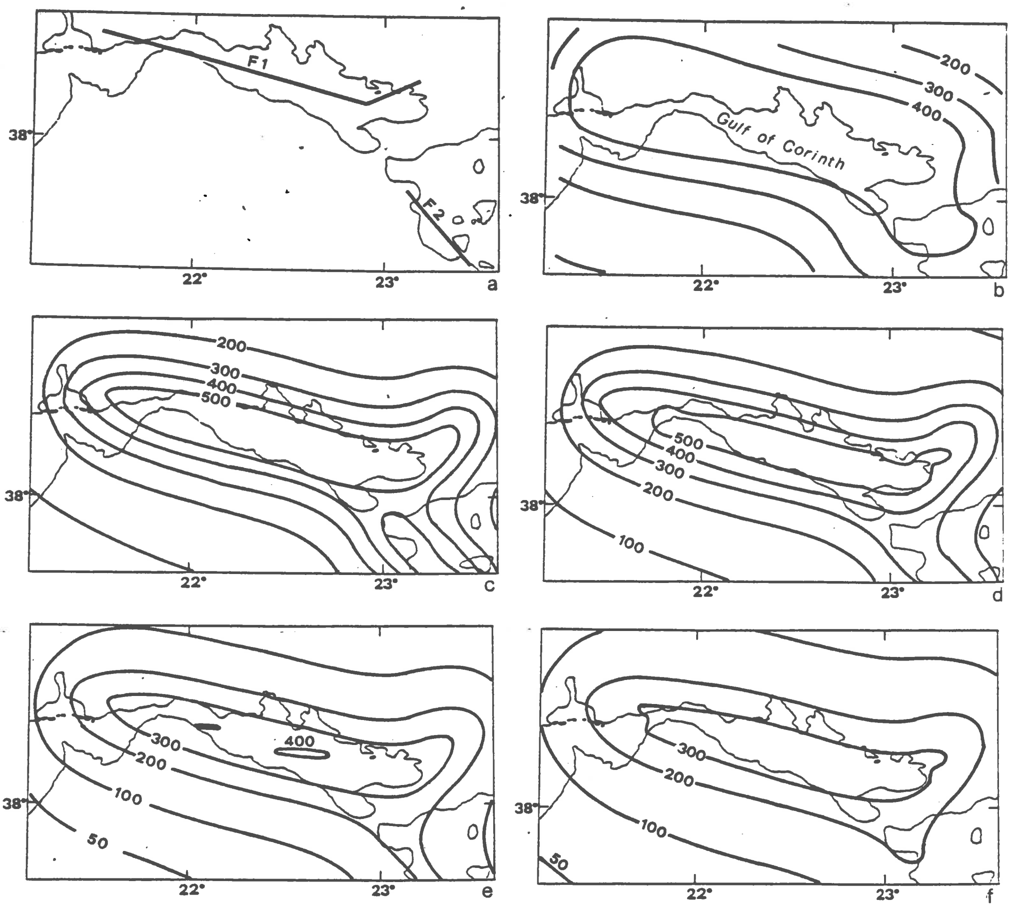

Fig. 2 - Fault model for the FRISK code (McGuire, 1978) and maximum PGA expected not to be exceeded at 37% probability in 100 years: a) seismic lines; b) SEISRISK (Bender and Perkins, 1987) application; c) FRISK average rate Makropoulos (1978) attenuation; d) FRISK individual rates Makropoulos attenuation; e) FRISK individual rates Papaioannou (1984) attenuation; f) FRISK individual rates Theodulitis (1991) attenuation.

seismicity is rather low, but this fact is not supported by relevant tectonic dishomogeneities. In the first case the seismicity rate of the whole region of the gulf of Corinth has been associated to both F1 and F2 faults. In the second the seismicity rates have been computed separately considering a wide area around the faults. The difference in the results refers only to the southeastern part of the study area, where lower values are reached with individual rates than using an average rate.

The analysis shows that the choice of the seismogenic model is dependent on the tectonic knowledge and relevant information in the study area, the FRISK model (McGuire, 1978) being most appropriate in regions where there is a good correlation of seismicity with well defined tectonic lines, like the gulf of Corinth, while the SEISRISK model (Bender and Perkins, 1987) should be applied to regions with more general knowledge or most complex tectonic regime.

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MAXIMUM EXPECTED EARTHQUAKE MAGNITUDES IN TURKEY ESTIMATED BY NONLINEAR LEAST-SQUARES AND MAXIMUM LIKELIHOOD TECHNIQUES

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INTRODUCTION

The maximum earthquake magnitudes can be estimated through the theory of extremes. Extreme value statistics developed by Gumbel (1958) provide a convenient method to obtain estimates of the frequencies of occurrence of earthquakes. The Gumbel's third distribution of extreme values (G3) is most suitable to seismic risk calculation. For estimating the G3 parameters, the nonlinear least-squares (NLS) and maximum likelihood (ML) techniques are considered outstanding in accuracy. In the present study G3 is used to estimate maximum magnitudes and return periods for earthquakes occurring in Turkey.

THE DATA SET

The catalogue published by Alsan et al. (1975), and Güclü et al. (1986) were updated by using ISC and PDE bulletins. The surface wave magnitude (M_S) is used. The modified Stepp's (1971) method, proposed by Burton et al. (1984), has applied and showed that the data ($M_S \geq 4.5$) between 1913-1989 are suitable for statistical forecasts in Turkey (Mindevalli, 1991). Figure 1 shows the epicenters of 1046 events used in the study area (36–41^{o}N - 26–45^{o}E).

EXTREME VALUE STATISTICS

The probability that M_S is an extreme value of the magnitude is given by the cumulative distribution function (Yegualp and Kuo, 1974):

$$G3(M_S) = e^{-\left[\frac{w - M_S}{w - u}\right]^k} \quad ; \quad G3(u) = 1/e \quad ; \quad G3(w) = 1 \; , \qquad (1)$$

where w is the upper limit to M_S, k is the shape parameter, and u is the characteristic value. If M_S's are extreme magnitudes during n successive years and ranked in order of increasing size, the probability value of i'th observation can be obtained through

$$G3_i(M_S) = \frac{i}{n+1} \quad (2a) \qquad ; \qquad G3_i(M_S) = \frac{(i - 0.44)}{(n + 0.12)}. \quad (2b)$$

For curve fitting purposes, (1) can be transposed to

$$M_S = w - (w - u)\,[\,-\ln(G3(M_S))\,]^{\lambda}, \qquad (3)$$

where $\lambda = 1/k$. (3) can be solved by NLS (Makropoulos and Burton, 1986) or ML (Al Abbasi and Fahmi, 1991) techniques for three unknown parameters, w, u, and λ. The values of G3(M_S) of (3) are already known through (2a) by ML and (2b) by NLS for various M_S's. The NLS technique uses the Marquardt algorithm, where as the ML technique uses the Newton-Raphson procedure to determine parameters of (3). After obtaining these parameters, the most probable maximum magnitude in a T year period is (Makropoulos and Burton, 1986):

$$M_S = w - (w - u)\,[\,\frac{(1 - \lambda)}{T}\,]^{\lambda}. \qquad (4)$$

RESULTS

The western Turkey (WT) is tectonically different than the eastern Turkey (ET). Therefore, the maximum expected earthquake magnitudes are calculated for WT through the seismicity of west of $33^o E$ and for ET through the seismicity of east of $33^o E$. The G3 parameters and M_S values expected over 75 years, estimated through NLS and ML are given in Table 1. The maximum M_S obtained from grid studies, which will be referred later, are also shown in Table 1. The return periods for various magnitudes through ML are shown in Table 2. Although medium size events may frequently occur in WT, large events (M_S=7.5) can more frequently occur in ET than WT. In order to locate maximum expected earthquake in Turkey, the area of 36-41^{o}N, 26-45^{o}E is divided into grids, first being 36-38^{o}N, 26-28^{o}E centered on 37^{o}N, 27^{o}E. The grid is moved eastwards by 1^o etc., thus developing an overlapping grid of point values. Grid point values of expected magnitudes over 75 years, calculated through NLS and ML, are given in Table 3. The maximum M_S is expected at 40^{o}N-30^{o}E of WT and 39^{o}N-40^{o}E of ET. These values are lower than the values obtained through whole data (without subdividing the region into grids), as they are indicated in Table 1 through *'s. The variations of NLS-ML in terms of M_S and as well as percentages are also indicated together with maximum observed M_S of each grid in Table 3. The average variation of NLS-ML is 2.19%.

CONCLUSIONS

The NLS and ML techniques are used for parameter estimation of G3. It is concluded that: 1)Although maximum expected earthquake magnitudes estimated using ML and NLS techniques are similar in Turkey, generally the values from NLS are higher than ML. However, when the results obtained in this study are compared with maximum observed magnitudes in Turkey, the values from NLS are more realistic, especially in ET, where return period of large earthquakes (M_S=7.5) is about 58 years. 2)Both techniques require initial estimates for G3 parameters (w,u, and k). However, ML is very sensitive to initial estimates. Sensitivity analysis through different combinations of initial estimates showed that for various good estimates Newton-Raphson procedure of ML converged to the same result through different iteration numbers. 3)Grid study indicated the locations of the estimated maximum earthquakes such as towards north of study area at WT and the intersection of North Anatolian and East Anatolian Faults at ET, where recent Erzincan Earthquake of Mar. 13, 1992 (M_S=6.8) took place.

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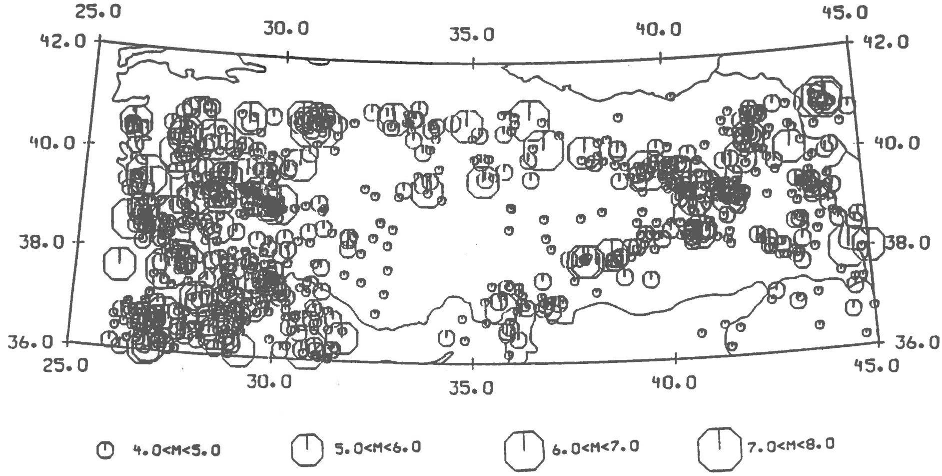

Figure 1. Epicenters of Turkish earthquakes for the period 1913-1989. Events M_S<4.5 are not included.

Table 1. Comparison of parameters estimated by using NLS and ML techniques.

Gumbel 3 Parameters								
Technique	w		u		k		M_S	
	WT	ET	WT	ET	WT	ET	WT	ET
NLS	7.84	10.67	5.44	5.17	2.19	6.94	7.58 (7.49*)	7.78 (7.44*)
ML	7.69	9.90	5.53	5.16	2.19	5.96	7.46 (7.41*)	7.67 (7.38*)

* Maximum M_S obtained from grid studies.

Table 2. Estimated return periods for Gumbel 3 distributions using ML.

Return Period (years)		
M_S	WT	ET
5.0	1.25	1.42
5.5	1.55	2.10
6.0	2.26	3.71
6.5	4.22	7,73
7.0	12.73	19.15
7.5	210.01	58.18
8.0	---	233.02

Table 3. Maximum expected earthquake magnitudes in Turkey by NLS and ML techniques.

Lat.-Long. (N) - (E)	NLS	ML	NLS-ML (%)	Max. Obs. M_S	Lat.-Long. (N) - (E)	NLS	ML	NLS-ML (%)	Max. Obs. M_S
37°–27°	7.12	7.06	0.06(0.85)	7.3	39°–27°	7.14	7.05	0.09(1.28)	7.0
37°–28°	7.37	7.29	0.08(1.10)	7.3	39°–28°	6.89	6.87	0.02(0.29)	7.0
37°–29°	6.99	6.95	0.04(0.85)	7.1	39°–29°	7.29	7.20	0.09(1.25)	7.3
37°–30°	5.97	5.43	0.54(9.95)	6.1	39°–30°	7.19	6.82	0.37(5.43)	7.3
37°–31°	6.62	6.58	0.04(0.61)	7.1	39°–31°	6.73	6.71	0.02(0.30)	7.1
37°–32°	5.90	5.43	0.47(8.66)	6.2	39°–32°	5.54	5.48	0.06(1.10)	5.5
37°–33°	*	*			39°–33°	*	*		
37°–34°	*	*			39°–34°	*	*		
37°–35°	6.00	5.95	0.05(0.84)	6.0	39°–35°	*	*		
37°–36°	5.97	5.91	0.06(0.17)	6.0	39°–36°	*	*		
37°–37°	5.51	5.50	0.01(0.18)	5.5	39°–37°	*	*		
37°–38°	*	*			39°–38°	*	*		
37°–39°	*	*			39°–39°	6.96	6.72	0.24(3.57)	7.9
37°–40°	*	*			39°–40°	7.44	7.38	0.06(0.81)	7.9
37°–41°	*	*			39°–41°	7.08	6.97	0.11(1.58)	7.0
37°–42°	*	*			39°–42°	6.80	6.62	0.18(2.72)	6.9
37°–43°	5.11	5.34	-0.23(-4.31)	5.1	39°–43°	5.97	5.90	0.07(1.19)	5.9
37°–44°	*	*			39°–44°	5.87	5.89	-0.02(-0.34)	5.9
38°–27°	7.16	7.09	0.07(0.99)	7.0	40°–27°	7.45	7.33	0.12(1.64)	7.4
38°–28°	7.07	6.99	0.08(0.14)	7.0	40°–28°	7.26	7.18	0.08(1.11)	7.4
38°–29°	6.88	6.80	0.08(1.18)	7.0	40°–29°	7.13	7.06	0.07(0.99)	7.3
38°–30°	5.98	6.00	-0.02(-0.33)	5.9	40°–30°	7.49	7.41	0.08(1.08)	7.3
38°–31°	5.91	5.87	0.04(0.68)	5.9	40°–31°	7.37	7.13	0.24(3.37)	7.2
38°–32°	5.69	5.62	0.07(1.25)	5.7	40°–32°	5.42	6.52	-0.10(-1.81)	5.7
38°–33°	*	*			40°–33°	6.71	6.55	0.16(2.44)	6.9
38°–34°	*	*			40°–34°	6.44	6.45	-0.01(-0.16)	6.6
38°–35°	*	*			40°–35°	6.30	6.16	0.14(2.27)	6.2
38°–36°	5.77	5.78	-0.01(-0.17)	6.0	40°–36°	7.11	6.87	0.24(3.49)	7.1
38°–37°	5.92	5.91	0.01(0.17)	6.3	40°–37°	7.29	6.95	0.34(4.89)	7.1
38°–38°	6.06	6.11	-0.05(-0.82)	6.3	40°–38°	6.60	6.67	-0.07(-1.05)	7.1
38°–39°	6.06	6.03	0.03(0.50)	6.3	40°–39°	6.96	6.62	0.34(5.14)	7.9
38°–40°	6.63	6.58	0.05(0.76)	6.8	40°–40°	7.22	6.63	0.59(8.90)	7.9
38°–41°	6.83	6.76	0.07(1.04)	6.8	40°–41°	7.07	6.63	0.44(6.64)	7.0
38°–42°	5.61	5.68	-0.07(-1.23)	5.7	40°–42°	6.97	6.46	0.51(7.89)	6.9
38°–43°	5.47	5.46	0.01(0.18)	5.5	40°–43°	6.76	6.28	0.48(7.64)	6.8
38°–44°	6.76	6.93	-0.17(-2.45)	7.6	40°–44°	6.63	6.70	-0.07(-1.05)	7.0

* too few data

SPACE-TEMPORAL SEISMICITY FEATURES OF THE BETIC-ALBORAN SEA REGION (SOUTHERN SPAIN), USING PRINCIPAL COMPONENTS AND CLUSTER ANALYSIS

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INTRODUCTION

The multivariate data analysis has great versatility and a wide range of possible uses in complex phenomena which have a great number of variables. The main common techniques used are: Principal Components Analysis (PCA), Cluster Analysis (CA) and Discriminant Analysis. Only a few of the researches have used PCA or CA techniques in seismicity studies. The PCA techniques were applied to the space distributions of aftershock sequence studies (e.g., Eblin and Michelini, 1986; Michelini and Bolt, 1986; Posadas et al, 1991). Cluster Analysis are more usually applied to determine cluster characteristic of earthquakes, looking at their time, space or space-time dependence (e.g., Frolich and Davis, 1985, 1990; Frolich, 1987; Gasperini and Mulargia, 1989; Reasemberg, 1985; Peña et al, 1992).

The Betic-Alborán region (Southern Spain) is a moderate seismic area which has experimented several historical and strong earthquakes with an intensity of IX degree or more (e.g., 1504, 1518, 1522, 1531, 1674, 1680, 1806, 1829, 1884, events). During the present century, only two earthquakes had a magnitude greater than 6.0 in the Betic Zone: on the 16 June, 1910 and on the 29 March, 1954 events, latter being 630 Km. deep (Vidal, 1986).

In this work, we apply the PCA and CA (using the single-linkage method) techniques to the earthquakes which occurred in the Betic-Alborán region in 1962-1990 period, with magnitude greater than or equal to 4.0. We have used the following variables: origin time, Longitude, Latitude, depth and magnitude, in order to discover the relevant seismicity tendencies of the region, the weight of each variable in the data set and, finally, the clustering features of the earthquakes.

DATA AND METHODS

The catalogue used contains the hypocentres of 163 earthquakes (m > 4.0), which took place during the 1962-1990 period, in the region situated between 35° and 40° N and between 0° and 7° W (Peña et al, 1992). This catalogue is complete for this period and range of magnitudes. The very deep earthquakes of 1973 and 1990 were not taken into account in this analysis of the region because these quakes were anomalous and showed a different seismicity pattern. The time variable considered is the time elapsed from 0h. 0m. 0s. on January 1, 1.962 to time of the event. The geographic coordinates were transformed into Lambert coordinates. All the variables have been standardized (average 0 and variance 1) in order to avoid the influence that some variables can have in the analysis due to their wide range of values. A first analysis leads us to consider several sets of data with different numbers of variables.

Principal Components Analysis is a technique of Multivariate Analysis and was first made up by Hotteling in 1933. With it, we can obtain the relationships among objects in a data set, discovering a new set of variables, Principal Components, which can summarize the data set information. This method can be briefly described in the following way: Take **X** as a matrix of quantitative data $\mathbf{X} = (x_{ij})$, $1 \leq i \leq n$, $1 \leq j \leq p$. In this case, **n** is the number of seismic events and **p** the number of variables (time, latitude, longitude, depth, magnitude). Each event can be considered as a point of a p-dimensional euclidean space R^p. PCA method obtains **p** new orthogonal axes, called Principal Components, $y_i = \Sigma a_{ij} x_j$, using the following conditions: y_1 maximizes the variance; y_2 maximizes the variance being orthogonal to y_1, y_3 maximizes the variance being orthogonal to y_1 and y_2, and thus repeatedly in the following way:

$$\sum_{k=1}^{p} a_{ik} a_{jk} = 0, \quad j < i, \quad \text{and} \quad \sum_{k=1}^{p} a^2_{ik} = 1, \quad \forall i$$

From a geometrical point of view, y_1 axis minimizes the distance between the data set and this axis; y_2 verifies this condition and it is also orthogonal to y_1, etcetera. Therefore, the best r-dimensional representation of the data can be found projecting the points of R^p on the subspace generated by $y_1, y_2, \ldots, y_r$, leading to a dimensionality reduction. (We established a classification of the magnitude (0.25 range) in order to discover possible energetical trends). With PCA method allows us to discover the following: The most useful variables, making a selection of features, how the variables are related among them, general trends in the data set, underlying variables and indications about groups of objects and outliers. The coefficients a_{ij} are obtained computing the eigenvalues and the eigenvectors of the correlation matrix, that is, solving the equations system: $(S - \lambda I)\,\mathbf{a}_k = 0$, where $\mathbf{a}_k = (a_{1k}, a_{2k}, \ldots, a_{pk})$ and $Var(y_k) = \lambda_k$. The values $a_{jk}\ \lambda^{1/2}$

represent the weight of the original variable x_k in the y_j component. These coefficients help find the most important sources of data variation and other underlying influences can not be observed in another way (a complete review appears for example in Dunteman (1974) and Kzranoswki (1988)).

Cluster Analysis techniques are focused to arrange a set of data into different groups of similar data. A clustering algorithm is then used to determine the inherent or natural groupings in the data as well as to identify isolate elements. In Cluster Analysis, we divide a set of observations in groups or clusters in such a way that most observations in the same group are more similar to each other (Jollife, 1.986). Cluster analysis of our data set initiate following common steps: Selection and standardization of variables (focal coordinates, magnitude and occurrence time), selection of a measure of association among data units (we employed euclidean distance) and application of a clustering criterion (we chose single-linkage algorithm). Single-linkage clustering, also known as the "minimum distance" or "nearest neighbour", is a SHAN method (Sequential, Hierarquical, Agglomerative and No overlapping) (a complete review appears in Andenberg (1973); Jain & Dubes (1988)). Its application to earthquake data classifies the quakes in groups and in isolated events, and it forms linear chain allowing to detect linear trends.

RESULTS AND CONCLUSIONS

1.- PCA (all data, t,x,y,p,m variables). The main results are: 1) There is a very little connection between each pair of variables. 2) Depth is not correlated with Latitude and magnitude (there are not defined trends implying depth). 3) Latitude and occurrence time are also not correlated. The first and the second principal components are:

$$y_1 = 0.60t - 0.74x - 0.39y + 0.63p - 0.32m \qquad y_2 = -0.49t - 0.26x - 0.70y + 0.07p + 0.70m$$

The data projection on the hyperplane determined by these components has an average of 56.8% of variance. Some of the most relevant earthquake features were observed at this stage.

2.- PCA (all data, t,x,y variables). The first two components obtained are:

$$y_1 = 0.34t - 0.73x - 0.83y \qquad y_2 = -0.9t + 0.04x - 0.47y$$

These first two components gather together 78.67% of variance. The first component is geographical and the second one is essentially temporal, so we can notice some geographic-time aspects of the seismicity in the region (Fig.1), and it can be observed that there are two time periods which must be study separately: 1962-1973 and 1974-1990. The main conclusions are: 1) The first period contains less quakes than the second one. 2) The quakes of highest magnitude (m=5.6) take place in the limit of both periods. 3) The average magnitude for the first period is higher than the second one. 4) There are more clustering during the first period than during the second one. In order to study in depth the two periods already detected, we are applying again PCA and CA to each period.

3.- PCA (1962-1973 period, all variables). The two first principal components obtained are:

$$y_1 = 0.47t - 0.81x - 0.48y + 0.53z - 0.13m \qquad y_2 = -0.19t - 0.04x - 0.72y - 0.35z + 0.79m$$

These components reach 54% of variance. One can notice that the first one is a space-time component and the second one is essentially space-energetical. Data projection on the plane Y_1Y_2 (Fig.2) shows some general features: Magnitude of the earthquakes decreases from S to N and also when time grows.

4.- PCA (1974-1990 period, all variables). The two principal components are:

$$y_1 = 0.12t - 0.79x - 0.74y + 0.57z - 0.03m \qquad y_2 = -0.8t + 0.06x - 0.05y + 0.24z + 0.83m$$

They achieve 58.2% of variance. Coefficients of linear correlation with the pairs **(t,m)** and **(x,y)** are now more significant (-0.37 and 0.37 respectively). This result and the projection of the data on the plane Y_1Y_2 (Fig. 3) make possible to come to the relevant conclusions:1) An evident decrease of magnitude as time grows. 2) A clear progressive increase of seismic occurrence as time increases.3) A moderate decrease of magnitude when Latitude increases.

Finally, PCA is applied in both periods using **t,x** and **y** variables and then one can observe the results mentioned before taking into account the magnitude ranges. In both periods, the first principal component obtained is clearly geographical and the second one is essentially temporal (virtually **t**).

5.- PCA (1962-1973 period, t,x,y variables). The two first principal components are:

$$y_1 = 0.17t - 0.82x - 0.82y \qquad y_2 = -0.99t - 0.12x - 0.09y$$

they both achieve 76% of variance and they give us the usual seismicity evolution model during this period as Fig. 4 shows. In this plot, two space-time features can be seen: Where the clusters exist and the repetitive way that seismic activity in this region takes place. On the other hand, energetic features can also be observed when looking at the symbols.

6.- PCA (1974-1990 period, t,x,y variables). The two components (78.67% of variance) are:

$$y_1 = 0.45t - 0.78x - 0.72y \qquad y_2 = -0.88t - 0.11x - 0.42y$$

The data projection shows similar as in the former period but not in such a clear way, probably due to the existence of a smaller average magnitude in this last period (Fig. 5).

7.- Applications of CA.

In this case, the results of clustering analysis using all variables are not significant. So that, we have taken into account only the more relevant variables (epicentral coordinates and occurrence time) which have the highest weight in the analysis. The CA results have been obtained thanks to dendrograms, SSE functions and geographic plots of the clusterings found. In the first period five clear clusters raise (Fig. 6a) in zones historical destructive earthquakes have occurred, mainly in the strong links obtained. New clusters raise in areas with similar characteristics in the second period (Gulf of Almería, Dalias, Málaga, S of Córdoba). In this last period weak linkages connect the Alborán Sea activity with the central and eastern part of the Betic activity. Some of linear trends appear in the analysis and are drawn in Fig. 6 and 7. They have nearly the same directions of some important faults. This results corroborate some of the ones obtained by Peña et al. (1992).

To conclude we confirm PCA and C methods as very good tools to analyze seismic activity. The main feature obtained is the hight importance of t,x,y variables in order to detect the relevant trends of this seismic data set. Bearing them in mind, it is possible to discover the most frequent way the seismic activity takes place in each area and the important interdependence among different source zones. The application of these methods to a wider time period and range magnitude in Betic-Alborán earthquake data must confirm and expand these results.

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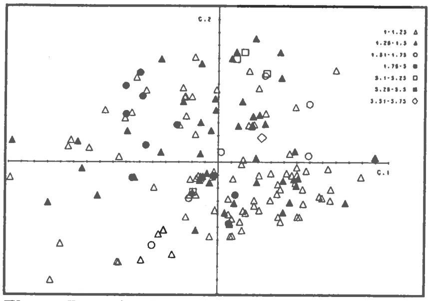

Fig. 1 Data projection on Y_1,Y_2 plane: all data, t,x,y variables.

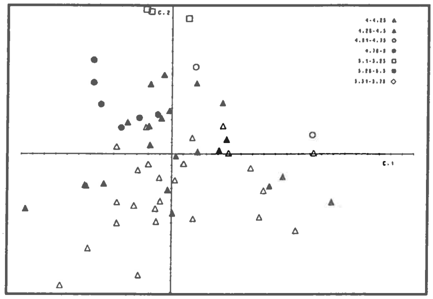

Fig. 2 As in Fig. 1, 1962-1973, all variables.

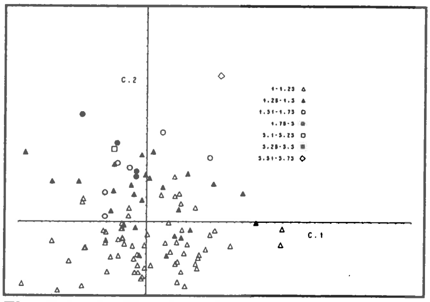

Fig. 3 As in Fig. 1, 1974-1990, all variables.

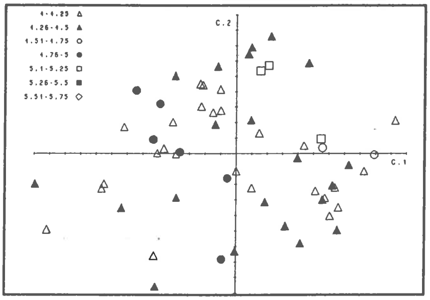

Fig. 4 As in Fig. 2, using t,x,y variables.

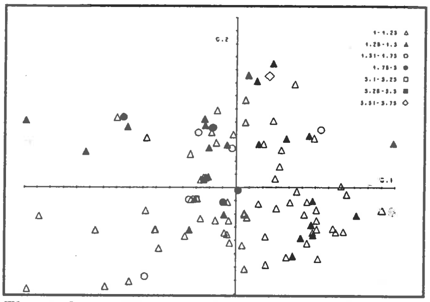

Fig. 5 As in Fig. 3, using t,x,y variables.

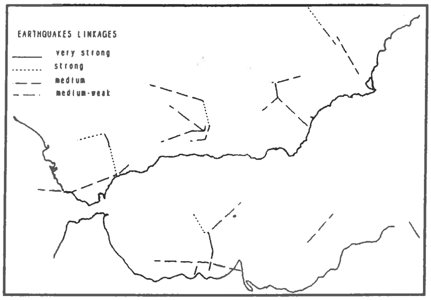

Fig. 6 CA earthquake linkages, 1962-1973.

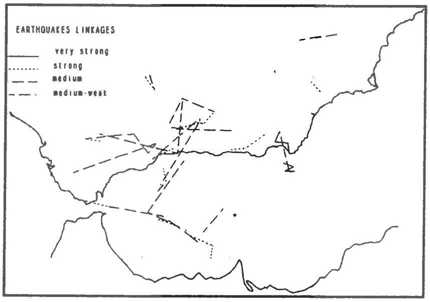

Fig. 7 CA earthquake linkages, 1974-1990.

HIGH-FREQUENCY $2\frac{1}{2}$-D MODELLING OF SEISMIC WAVE-FIELDS APPLIED TO A FINITE EXTENT SOURCE SIMULATION

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INTRODUCTION

The wave-field modelling, which is based on a 2-D solution of the wave or elastodynamic equation, is predestined to have limited use. Practical needs often lead to 3-D solutions even in those cases, when the structure itself can be considered as 2- or 1-dimensional. In such cases, $2\frac{1}{2}$-D modelling can be very useful. Although, the term $2\frac{1}{2}$-D modelling refers sometimes to *in-plane* computations (in the plane of the symmetry of a 2-D model), in this contribution it means the computation of general 3-D rays of body waves propagating in any direction through the structure considered.

In the range of its applicability, $2\frac{1}{2}$-D modelling is more effective than fully general 3-D approach, giving exactly the same 3-D results. It is based on substantially simplified ray tracing and offers therefore considerable savings of computer time.

This method has many applications and significantly extends applicability of 2-D structure models, used still very often in seismology, mainly due to the lack of sufficient 3-D data concerning the earth's structure. The $2\frac{1}{2}$-D approach is especially useful in such cases, when a general source-receiver configuration is to be modelled. This is very common in connection with the simulations of finite extent sources oriented arbitrarily with respect to receivers as well as to of the structure.

$2\frac{1}{2}$-D RAY COMPUTATIONS

Suppose, the following 3-D ray tracing system in Cartesian coordinates to be solved in a 2-D region:

$$\frac{dx_i}{d\tau} = v^2 p_i, \quad \frac{dp_i}{d\tau} = -\frac{1}{v}\frac{\partial v}{\partial x_i}, \quad i = 1, 2, 3,$$

with initial conditions $x_i = x_i^0, p_i = p_i^0$. The symbol v denotes either the P or S wave velocity. Let the medium does not vary along the x_2 axis. Then, the solutions for x_2 and p_2 can be sought separately to yield the analytical expressions:

$$p_2 = p_2^0 = const, \quad x_2 = x_2^0 + p_2^0 \int_{\tau_0}^{\tau} v^2\, dt.$$

Remaining ray tracing equations can be handled, in principle, using any standard 2-D routine available. The only difference here, is that p_1 and p_3 must satisfy the modified eikonal equation: $p_1^2 + p_3^2 = v^{-2} - (p_2^0)^2$. The general law of ray reflection/transmission (Červený 1977) yields, that the p_2 component remains constant not only in a smooth medium, but also across any structural interface.

In many applications, ray centered coordinate base vectors or S-wave polarization vectors, related easily to them, are necessary to be known. To compute the complete set of these vectors, a general 3-D approach must be used. The same holds, for instance, when the dynamic ray tracing system is solved in ray centered coordinates.

NUMERICAL EXAMPLES

The method is demonstrated on a typical, laterally varying, isotropic, earth's crust model. The parameters of the model are in Tab. 1, the shape of interfaces can be seen on Fig. 1, where also the example of the ray-fields considered in this numerical experiment is plotted. The point source, generating either P, or S waves, is situated at the range $x_1 = 320$ km and the depth $x_3 = 10$ km. Only monotypic waves are taken into account.

"interface"	α_1	α_2	β_1	β_2	ρ_1	ρ_2
top	-	4.00	-	2.31	-	2.50
1-st	6.00	6.00	3.46	3.46	2.90	2.90
2-nd	6.60	7.00	3.81	4.04	3.02	3.10
3-th	7.60	8.20	4.39	4.73	3.22	3.34
bottom	8.30	-	4.79	-	3.36	-

Tab. 1: Structure parameters above (1) and below (2) the interfaces. Inside the layers they are approximated linearly along vertical lines.

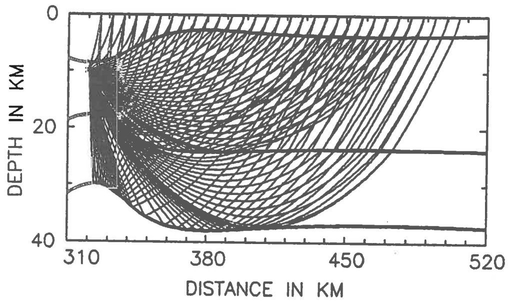

Fig. 1: The plane rays of the profile A.

The rays are shot to terminate on surface line profiles, A – F, starting at the epicentre with the azimuths 0° – 75° (by 15°). The horizontal projections of all the considered rays, showing how the rays deviate from vertical planes containing the profiles, are on Fig. 2.

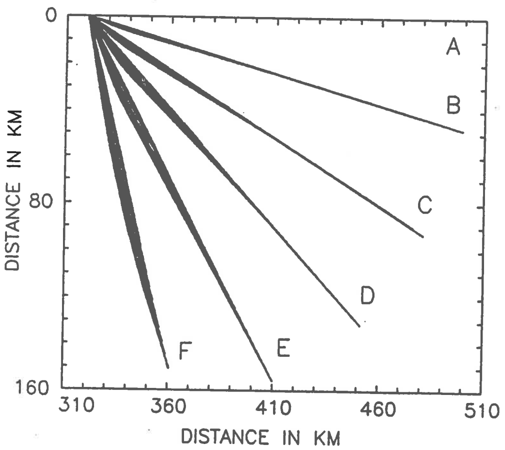

Fig. 2: Map view of the rays terminating on the considered profiles. The rays of the profile A coincide with the range axis.

Fig. 3 shows the initial azimuths of the rays plotted against the epicentral distance at which they terminate. It proves that the rays of individual phases, recorded along a given profile, pass through different parts of the structure outside the profile. This is also the reason, why the rays refracted and reflected in one layer may not reach the same maximum epicentral distance, as it should be in the plane of the symmetry (profile A) of this model.

Various factors, depending on azimuth, contributing to the resultant wave-field, have been investigated. Very interesting one is the nonzero torsion of rays. In order to visualize better this feature, specific source generating mainly SH waves (for each profile) was assumed. The torsion is than manifested on the nonzero vertical component of the ray amplitude, especially for the profiles C and B, see Fig. 4. For deeper phases (the lower parts of the figure) the torsion is combined with another effect, caused by the sloping interfaces. Outside the $x_1 - x_3$ plane, a nonzero vertical displacement is generated at the interfaces, even by the wave polarized horizontally.

How much the torsion itself may be essential for synthetic seismograms is shown on Fig. 5. At one specified receiver (108 km) of the profile C (30°) the wave-field is computed by two ways: using the correct $2\frac{1}{2}$-D approach (left) and by an approximate approach simulating *in plane* modelling, where along the correctly computed ray, the ray centered base vectors are evaluated with the torsion neglected (right). The difference is very conspicuous.

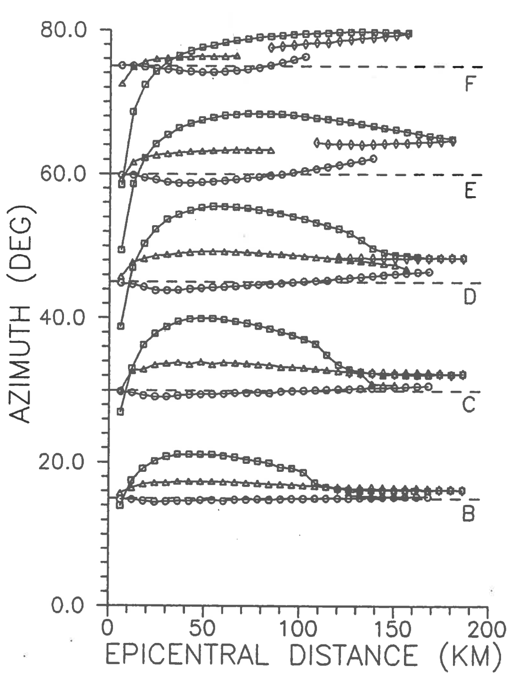

Fig. 3: Initial azimuths of the rays; ○ △ ◇ □ hold for the individual waves from the shallowest phase to the deepest one.

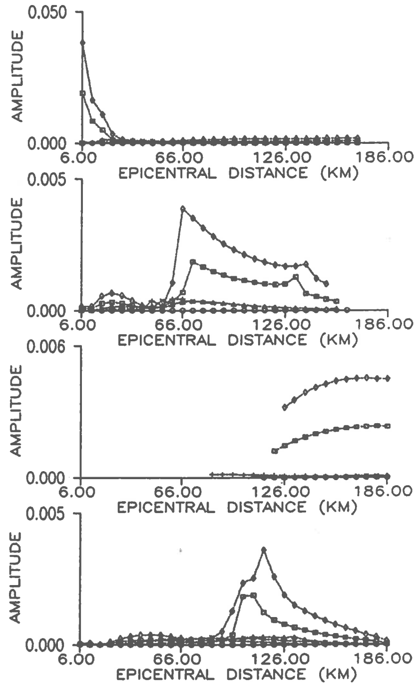

Fig. 4: Vertical component of the ray amplitude (not including radiation pattern) of the wave polarized like SH at the source.

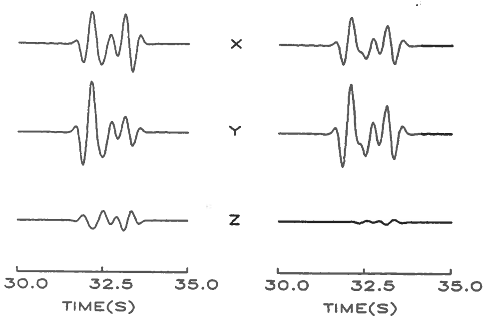

Fig. 5: Comparison of the correct $2\frac{1}{2}$-D computation (left column) and a quasi 2-D computation simulating zero torsion (right column) at one specified receiver on the profile C: vertical component of the displacement due to the double couple source generating mainly SH waves.

The $2\frac{1}{2}$-D modelling can be applied as a very useful tool for finite extent source simulations in laterally varying structures. Fig. 6 presents one example of such a kind of computation. In the same model as that handled in the above discussed parametrical study, the horizontal line source representing a very narrow left lateral fault, 2 km long, is considered. The source, center of which is again at $x_1 = 320$ km and $x_3 = 10$ km, lies entirely within the plane $x_1 - x_3$, while the wave-field is recorded along the profile C with the azimuth of 30°. Rupture propagates uniformly from the right to the left with the velocity 3 km/s. Thus, the above mentioned structure effects are combined with the effects due to the finiteness of the source, like, e.g. strong directivity apparently manifested on this figure.

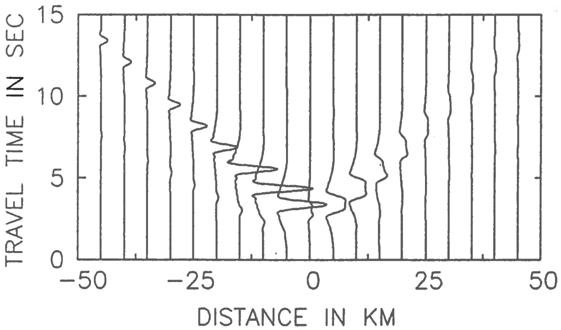

Fig. 6: Finite source wave-field along the profile C: transverse component (in the x_2-direction).

CONCLUSIONS

The method of $2\frac{1}{2}$-D modelling represents the correct ray-based solution applicable in 2-D structures, without any approximations and neglects. The approach is more effective than fully general 3-D modelling, giving exactly the same results. The method finds a wide class of applications and may become a significant contribution for finite extent source modelling.

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AN INVERTION METHOD TO DETERMINE THE CRUSTAL STRUCTURE AT THE EAST CARPATHIAN SEISMIC NETWORK STATIONS USING P-WAVE SEISMOGRAMS

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CALCULATION OF SYNTHETIC SEISMOGRAMS

Here we give a brief summary of the Thomson-Haskell technique (Verbytskyj et al., 1985) as it is used in our work.

Consider a solid halfspace which consists of isotropic homogeneous elastic horizontal layers. The lower layer has an infinite thickness. The layers are characterized by thickness, density, P- and S-wave velocities d_j, ρ_j, v_{P_j}, v_{S_j}. The equation of motion for the displacement vector $\mathbf{u}$ has the form $\rho\,\ddot{\mathbf{u}} = (\lambda + 2\mu)\nabla(\nabla\,\mathbf{u}) - [\nabla\,[\nabla\,\mathbf{u}]]$. The displacement vector $\mathbf{u}$ in the j-th layer may be represented by introducing the scalar and vector potentials ϕ_j, Ψ_j $(\nabla\,\Psi = 0)$ as $\mathbf{u}^{(j)} = \nabla\phi_j + [\nabla\,\Psi_j]$, $j=1,\ldots,N$. The vector Ψ_j is represented as the scalar ψ_j in a plane case. Solution of the equations for the elastic potentials ϕ_j, ψ_j in the j-th layer is obtained in the frequency ω and the horizontal wave number k domain. Introducing vector-columns $\bar{\mathbf{S}}_j(z) = [\bar{u}_x^{(j)}(z), \bar{u}_z^{(j)}(z), \bar{\sigma}_{zz}^{(j)}(z), \bar{\sigma}_{xz}^{(j)}(z)]^T$ and $\bar{\mathbf{\Phi}}_j(z) = [\bar{\phi}_j^{+}(z), \bar{\psi}_j^{+}(z), \bar{\phi}_j^{-}(z), \bar{\psi}_j^{-}(z)]^T$, where $\bar{u}_x^{(j)}(z)$, $\bar{u}_z^{(j)}(z)$, $\bar{\sigma}_{zz}^{(j)}(z)$, $\bar{\sigma}_{xz}^{(j)}(z)$ - components of the displacement-stress vector in ω and k domain; $\bar{\phi}_j^{+}(z)$, $\bar{\psi}_j^{+}(z)$, $\bar{\phi}_j^{-}(z)$, $\bar{\psi}_j^{-}(z)$ - longitudal and transverse potentials in ω and k domain of P- and S-waves propagating in up and down directions we have the following relations for each point in the j-th layer

$$\bar{\mathbf{S}}_j(z) = \mathbf{T}_j\,\bar{\mathbf{\Phi}}_j(z), \qquad \bar{\mathbf{\Phi}}_j(z) = \mathbf{T}_j^{-1}\bar{\mathbf{S}}_j(z),$$

where $\mathbf{T}_j$ is matrix 4×4 with the elements dependent of $v_{P_j}^2, v_{S_j}^2, \rho_j$, k, ω. The elastis potentials at the j-th boundary and at the (j-1)-th boundary are connected with the relation

$$\bar{\mathbf{\Phi}}_j(z_j) = \mathbf{E}_j\bar{\mathbf{\Phi}}_j(z_{j-1}),$$

where $\mathbf{E}_j$ is a diagonal matrix. Boundary conditions at the j-th boundary has a form $\bar{\mathbf{S}}_{j-1}(z_j) = \bar{\mathbf{S}}_j(z_j)$. The propagator matrix of the uniform layer according to (Dunkin, 1965) is determined by a recurrent relation

$$\bar{\mathbf{S}}_j(z_j) = \mathbf{G}_j\,\bar{\mathbf{S}}_j(z_{j-1}), \quad \text{where } \mathbf{G}_j = \mathbf{T}_j\,\mathbf{E}_j\,\mathbf{T}_j^{-1}.$$

So, we have at the (N-1)-th boundary

$$\bar{\mathbf{\Phi}}_N(z_{N-1}) = \mathbf{T}_N^{-1}\mathbf{T}_{N-1}\mathbf{E}_{N-1}\mathbf{T}_{N-1}^{-1}\ldots\mathbf{T}_1\mathbf{E}_1\mathbf{T}_1^{-1}\bar{\mathbf{S}}_1(z_0),$$
$$= \mathbf{R}\,\bar{\mathbf{S}}_1(z_0).$$

We consider plane P-wave with the horizontal phase velocity c which is insident on the (N-1)-th boundary from depth. In this case $k = \omega/c$, $\bar{\Phi}_N^+ \equiv 0$ and $\bar{\sigma}_{xz}^{(0)} = \bar{\sigma}_{zz}^{(0)} = 0$, so

$$\begin{bmatrix} \bar{\Phi}_N^+ \\ 0 \\ \bar{\Phi}_N^- \\ \bar{\Psi}_N^- \end{bmatrix} = \begin{bmatrix} r_{11} & r_{12} & r_{13} & r_{14} \\ r_{21} & r_{22} & r_{23} & r_{24} \\ r_{31} & r_{32} & r_{33} & r_{34} \\ r_{41} & r_{42} & r_{43} & r_{44} \end{bmatrix} \begin{bmatrix} \bar{u}_x^{(0)} \\ \bar{u}_z^{(0)} \\ 0 \\ 0 \end{bmatrix}$$

From the above equation we have

$$\bar{u}_x^{(0)} = -\frac{r_{22}}{r_{21}} \bar{u}_z^{(0)}.$$

Thus we can obtain horizontal component of the synthetic seismogram $\bar{u}_x^{(0)^t}$ for the some assumed model substituting $\bar{u}_z^{(0)}$ by the vertical component of the observed seismogram $\bar{u}_z^{(0)^e}$

$$\bar{u}_x^{(0)^t} = -\frac{r_{22}}{r_{21}} \bar{u}_z^{(0)^e},$$

and compare $\bar{u}_x^{(0)^t}$ with the horizontal component of the observed seismogram $\bar{u}_x^{(0)^e}$. So, it is possible to get the optimal model regardless of the seismogram source type.

INVERTION METHOD

The vector $\mathbf{M}$ consisting of the M independent model parameters is searched to minimize the norm

$$A = \sum_{l=1}^{L} | \mathbf{U}^{(l)} - \mathbf{F}^{(l)}(\mathbf{M}) |^2 = \sum_{l=1}^{L} \sum_{i=1}^{\Omega} (U_i^{(l)} - F_i^{(l)}(\mathbf{M}))^2,$$

where $\mathbf{U}^{(l)}$ is Ω-component vector of the discrete Fourier spectrum of the l-th experimental seismogram horizontal component, $\mathbf{F}^{(l)}(\mathbf{M})$ is the vector of the discrete Fourier spectrum of the l-th theoretical seismogram horizontal component. Linearizing the relation $\mathbf{F}^{(l)}(\mathbf{M})$ in the neighbourhood of the model $\mathbf{M}^{(k)}$, $k = 0,1,2, \ldots$ we have the following expression

$$A = \sum_{l=1}^{L} | \mathbf{D}^{(l)} - \mathbf{G}^{(l)} \mathbf{m} |^2,$$

where $G_{ij}^{(l)} = \left[\frac{\partial F_i^{(l)}}{\partial M_j} \right]_{\mathbf{M}=\mathbf{M}^{(k)}}$, $\mathbf{D}^{(l)} = \mathbf{U}^{(l)} - \mathbf{F}^{(l)}(\mathbf{M}^{(k)})$, $\mathbf{m} = \mathbf{M} - \mathbf{M}^{(k)}$.

Let matrix $\mathbf{G}$ and vector $\mathbf{D}$ have the form

$$\mathbf{G} = \begin{bmatrix} \mathbf{G}^{(1)} \\ \vdots \\ \mathbf{G}^{(L)} \end{bmatrix}, \quad \mathbf{D} = \begin{bmatrix} \mathbf{D}^{(1)} \\ \vdots \\ \mathbf{D}^{(L)} \end{bmatrix}.$$

Here we use the damped least square solution of the linearized problem

$$\hat{m} = (\tilde{G}G + \varepsilon^2 I)^{-1}\tilde{G}D,$$

where $\tilde{G} = (G^*)^T$ is complex conjugated and transposed matrix to **G**, **I** is a unit matrix, ε^2 is a regularizing parameter (Aki and Richards, 1980).

The reliability of the developed invertion method was checked by passing special simulation test. The synthetic seismogram for the some assumed five layered model was used to produce 20 noised (in amplitude range 5-10%) seismograms. These seismograms substituted the observed ones in fitting the slightly changed model to the initial one. The iteration process converged to the initial model after 8 steps.

APPLICATION TO REGIONAL SEISMIC DATA

The developed technique was used to correct models of the crust structure under the East Carpathian seismic network stations "Uzhgorod", "Mizhgirya", "Rakhiv", "Kosiv". Here we present the results for "Uzhgorod" station only because of the restricted volume of the paper. The station is located near the north edge of the Pannonian plain (Fig. 1). It allows to assume the crustal structure under the station to be horizontally layered. The initial model is taken from the IV-th International Geotraverse data. 22 far field seismograms registered by the station with the epicentres located within 15° sector were fitted simultaneously. The process had converged after the 15 iteration steps. The upper line on the Fig. 2 (left part) shows the experimental seismogram registered on June 11-th, 1981 with the epicentre parameters 29.75° N, 57.75° E. Theoretical seismogram for the initial model is shown here in the lower line. In the right part of the Fig. 2 the above mentioned experimental seismogram (the upper line) and the theoretical one for the final model obtained after processing 22 experimental seismograms are displayed in comparison with the curves demonstarted on the left part of the Fig. 2. The coincidence of the time arrivals of the amplitude peaks at 40 and 55 seconds is easily seen. The nearing of the amplitude values especially at 45 seconds are also observed.

On the Fig. 3 the initial Earth's crust model under the "Uzhgorod" seismostation is shown by squares. The model obtained after the process of crust structure correction is plotted with the triangles. The errors are plotted with the horizontal bars.

Fig. 1. The map of the East Carpathian seismic network stations location.

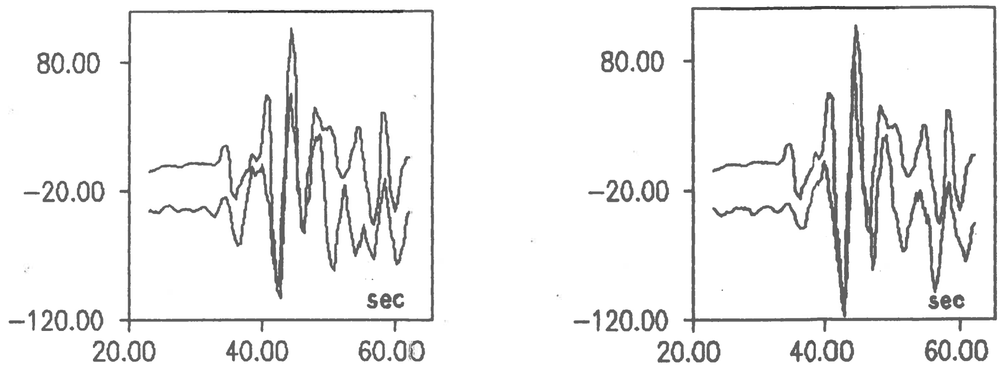

Fig.1. The comparison of the experimental seismogram observed on June 11-th, 1981 (upper line) and the synthetic seismogram (lower line) for the initial model (left figure) and for the resulting model (right figure) obtained after processing of 22 seismograms registered by "Uzhgorod" seismostation.

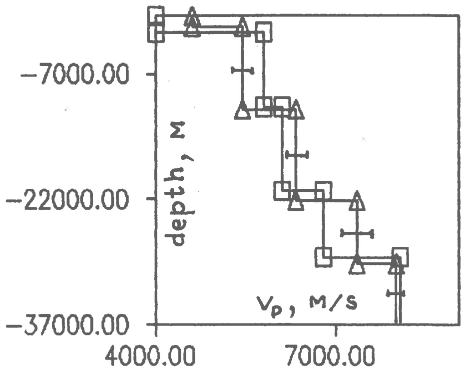

Fig.2. Initial (□) and resulting model (Δ) for the "Uzhgorod" seismostation.

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REFRACTION 3-D SEISMIC MEASUREMENTS IN WESTERN BOHEMIA

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CHARACTERISTICS OF THE REGION

Kraslice region is a seismically active part of the Bohemian Massif. The earthquakes are situated in the brittle upper part of the crust above the deep-seated suture intersecting the entire lithosphere, and at its crossings with transverse faults (Babuška and Plomerová, 1987). In the region, the occurrence of earthquakes is typical in swarms yielding a huge amount of data related to the source mechanism. The maximum observed intensity of the events was not greater than 7° MSK (Zahradník et.al., 1987). The region has been given great attention by both Czech and German seismologists. The area is situated between the KTB borehole (FRG) and the MVE seismic refraction profile (FRG). The 3-D geological structure of Western Bohemia is considerably laterally inhomogeneous and at least transversally anisotropic. The purpose of seismic refraction measurements is to estimate 3-D velocity distribution.

REFRACTION DATA

The Geofyzika Brno company performed 2-D refraction measurements along the profiles A/89, B/89, C/91 and D/91 in the years 1989 and 1991 (see Fig.1). The explosions on the profiles C/91 and D/91 were also registered by the Geofyzika Brno telemetry network in the Kraslice region (5 stations). In addition, the shots at 4 distinct locations along the profile C/91 were recorded at 20 measurement points spread over Western Bohemia. The portable digital recorders were operated by the Geophysical Institute and the Institute of Geotechnics. Similarly, shots along D/91 were recorded by the portable recorders at 8 measurement points.

The experiment MVE was carried out by German institutions in the area of the Federal Republic of Germany in 1990. The MVE/90 shots were recorded by the geophone profile of Geofyzika Brno. The geophone profile, parallel with the MVE/90 profile, was situated southerly to Mariánské Lázně (Fig.1). In addition, most of the MVE/90 shots were recorded by 14 portable digital recorders alternately at about 20 measurement points, irregularly spread over Western Bohemia. The 14 portable solitary stations were operated by Geofyzika Brno, the Geophysical Institute and the Institute of Geotechnics,.

All the refraction data were measured by digital recorders with the sampling frequency of 125 or 250 Hz. Approximately 1700 P wave travel times with various errors have been picked. Many of the seismograms have three components and a lot of them contain also S waves. The picking of S waves is more complicated and the errors of travel times are generally greater. Figure 2 demonstrates P wave travel times picked with an absolute error up to 40 ms plus a relative error up to 2%, situated within the area in question. The travel times are sorted out into 6 subfigures according to their length.

PROBLEMS OF INVERSION

Two 2-D velocity sections have been obtained by means of 2-D tomography along the A/89 and B/89 profiles (Dvořák and Sýkorová, 1990). Data from the C/91 and D/91 profiles are also subject to 2-D processing.

The 3-D data coverage is extremely uneven. Large areas are not covered by short rays (Fig.2). This prevents us from estimating velocities in shallow parts of the model in the areas and distinguishing them from the velocities in depth. There is also a lack of long rays in the east-west direction. Thus additional refraction measurements are desirable to allow for 3-D tomographic inversion. Much denser data coverage, for example, along 2-D refraction profiles than in other regions also prevents us from employing ordinary damped least squares during 3-D iterative tomographic inversion. Smoothing and interpolation of velocities during inversion is inevitable and has to be applied locally by means of weighting functions according to the data coverage. The corresponding methods and computer code have not been developed yet.

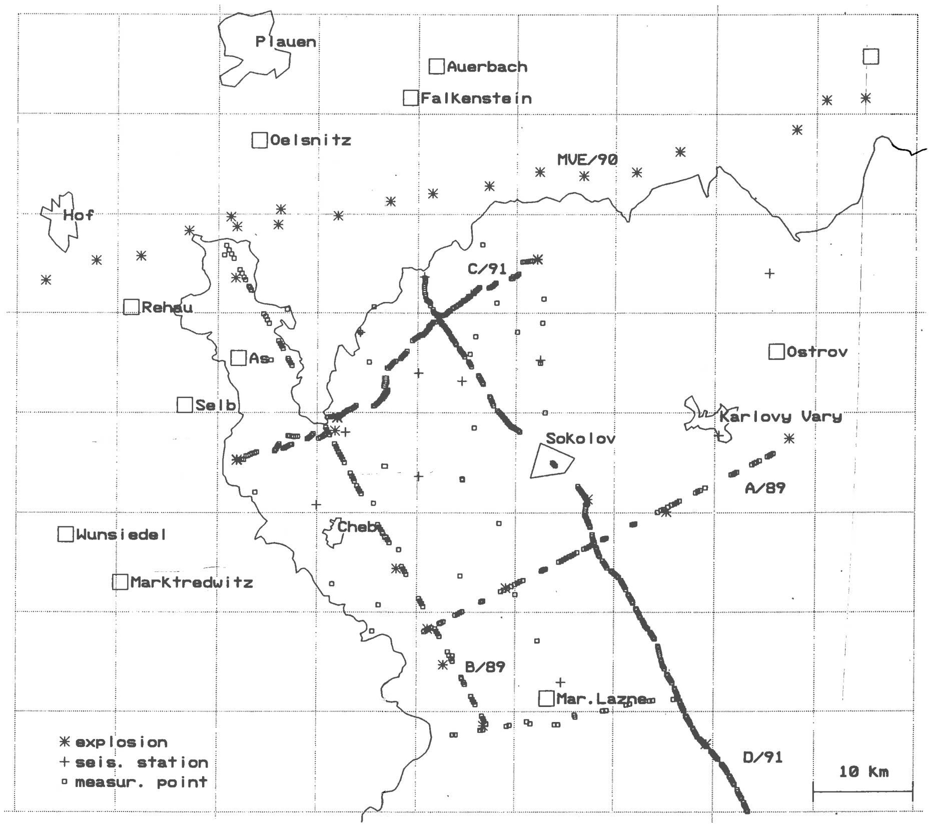

Fig.1. Map of Western Bohemia and adjacent area, representing the location of refraction explosions, seismic stations and temporary measurement points.

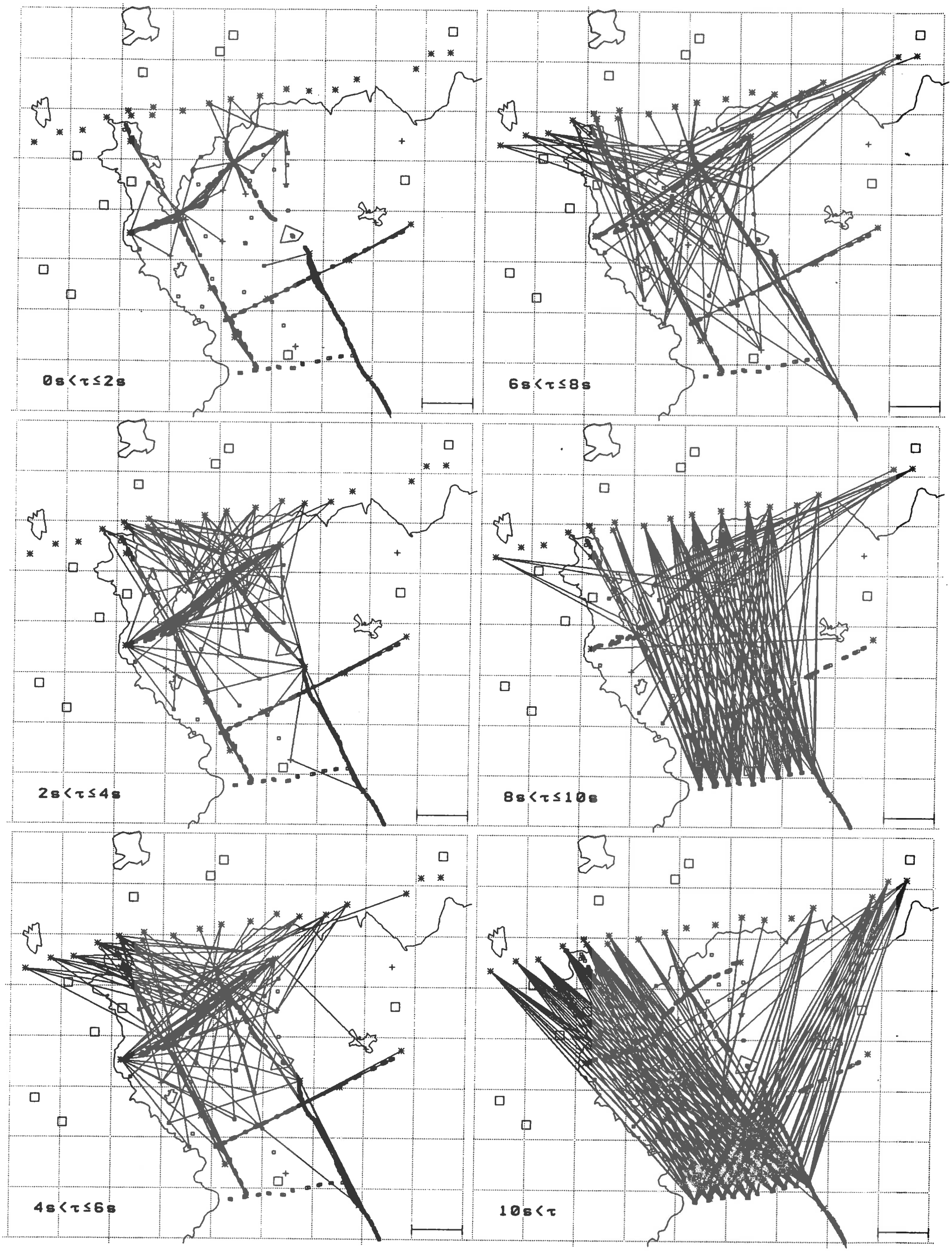

Fig.2. Travel times τ sorted according to their length.

CONCLUSIONS

a) Additional refraction travel times in the region should be collected before the 3-D tomographic inversion.

b) A theory, algorithms and computer code for 3-D seismic refraction tomography with locally weighted smoothing have to be developed.

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SEISMOLOGICAL STUDIES OF BOUNDARIES OF THE EARTH'S CORE

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INTRODUCTION

Recent studies have shown the presence of inhomogeneous structures down to the core-mantle boundary (CMB) (e.g. Dziewonski, 1984). Especially the lowermost mantle, the so-called D"-layer, seems to be one of the most inhomogeneous region of the Earth's interior (Lay, Helmberger, 1983; Weber, Körnig, 1992). Geodynamical and geochemical considarations (Stacey, Loper, 1983; Knittle, Jeanloz, 1989, 1991) support inhomogeneous structure of D". Mostly seismological studies of this region are carried out by means of refracted or reflected body waves. Due to short wave paths within the D"-layer (thicknes of about 190 km) those waves are not influenced very much by inhogeneities of this region. But there are seismic waves propagating over relative long distances within the inhomgeneous layer near CMB and being strongly influenced by them. That are diffracted waves (P_{diff}, S_{diff}). Their field is not regular. It has interference character. So one has not to use ray-methods for its description. In this study the asymptotic boundary layer method of diffraction was used (Babich, Buldyrev, 1991).

METHOD

The main idea of the method includes not the direct solution of the wave equation for interference waves propagating along a curved interface of inhomogeneous media which is not existing at all, but the analysis of the high frequency approximation of wave phenomena in a layer near the boundary of $\approx O((2\pi f)-2/3)$ thickness. The solution is then extended by means of ray theory into the whole Earth model. The used approach allows to describe a whole set of interference waves, diffracted P ,S, and whispering gallery waves propagating in an inhomogeneous layer near the curved internal boundary. So simple formulaedescribing the velocity and amplitude behavior of diffracted waves are derived:

$$v_P = v_p\,[1-(a\,v_p\,T/R_{eff})^{2/3}] \qquad \text{for } P_{diff}, \tag{1}$$

$$v_{SH} = v_s\,[1-(b\,v_s\,T/R_{eff})^{2/3}] \qquad \text{for } SH_{diff}, \tag{2}$$

$$v_{SV} = v_s\,[1-(c\,v_s\,T/R_{eff})^{2/3} - d\,v_s\,T/R_{eff}] \qquad \text{for } SV_{diff}, \tag{3}$$

where a, b, c are constants, v_p, v_s - the velocities of P- and S-waves in D",respecttively, T is the period, and d a parameter depending also on velocity and velocity gradient within the outer core. The effectice radius of the interface (CMB) is determined by

$$R_{eff} = [1/R - grad(v)/v]-1 , \tag{4}$$

where R stands for the radius of core, v for velocity, and grad(v) for the vertical velocity gradient of the respective type of wave. Inhogeneous structure is included by introducing path depending velocity and gradient at CMB. The most important feature of P_{diff} and S_{diff} is the dispersion. S_{diff}-waves show additional splitting for different polarization, i.e. the velocity of SH and SV phases is different. The examination of formulae (1)-(3) shows that the most important factors determining the velocities of diffracted waves are the P- and S-wave velocities and their vertical gradients, whereas a change of the radius of the curvature (CMB) is influencing diffracted waves orders of magnitude less.By (2) and (3) it is obvious that the analysis of vertically and horizontally polarized S_{diff} provides a tool for studying properties of CMB not only from above (D") but also from below (uppermost part of the liquid outer core). Studies of D" should be provided by means of both SHdiff and SV_{diff}, whereas of the outermost core only by SV_{diff}. Due to the small amplitudes of SV_{diff} it is an experimentally complicated problem. Polarization analysis and matched filtering should be applied.

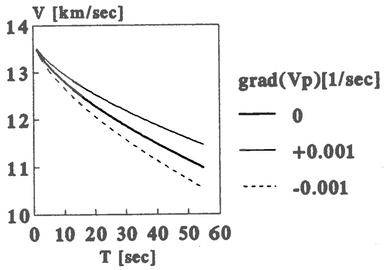

Fig. 1. Dependence of P_{diff} velocity on the vertical gradient within D".

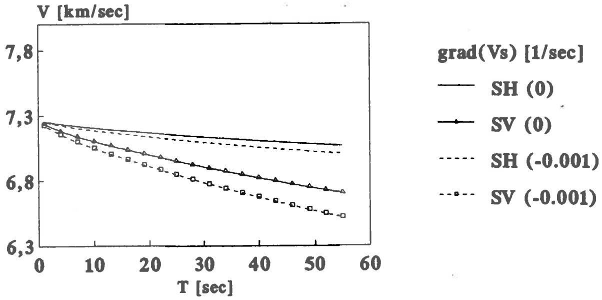

Fig. 2. S_{diff} splitting for different models of the D"-layer.

Theory predicts the formation of whispering gallery waves at CMB by incident S-waves. Velocities of those waves are described by similar formulae like diffracted waves (Krauklis et al.,1991), but the constants are determined by properties of the outermost core and negative, so that velocity increases with period. Whispering gallery waves are strongly attenuated with depth. Therefore a penetration depth into the outer core is defined by

$$h = e\, R_{eff}^{1/3}\, (v_s\, T)^{2/3}\ , \tag{5}$$

where e is a parameter incorporating the order of wave mode. Due to the dependence of penetration depth on the period T a selective illumination of the outer core should be possible by means of whispering gallery waves. The attenuation of whispering gallery waves is described by Q

$$Q = \pi\, R_{eff}/(g\ v\ T)\ , \tag{6}$$

where g is a factor depending on properties above and below the interface. For periods of about 1 sec Q is as large as 1000 (Fig. 3).

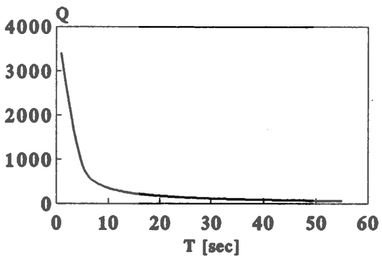

Fig. 3. Dependence of Q of whispering gallery waves at CMB on period.

For the inner core boundary theory predicts diffracted and whispering gallery waves, too. But one has to take into account that there a liquid is laying above the solid inner core. Therefore some non-principal changes in the formulae occur (Krauklis et al., 1991). Diffracted as well as whispering gallery waves at the inner core boundary are strongly attenuated. For T = 1 sec Q for both types of waves is smaller than 100.

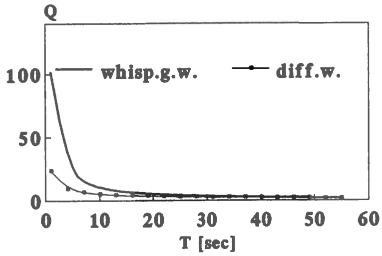

Fig. 4. Q of diffracted and whispering gallery waves at the inner core boundary.

DATA

The predicted phenomnena, especially P_{diff} and S_{diff}, were studied by means of digital seismograms of the GDSN. For determining the dispersion of P_{diff} the seismograms were bandpass filtered. Fig. 5. shows the azimuthal variations of frequency dependence of P_{diff}. For S_{diff} the seismograms were rotated into ray centered coordinates. Using polarization and/or matching the splitting of horizontally and vertically polarized S_{diff} was observed (Fig. 6.).

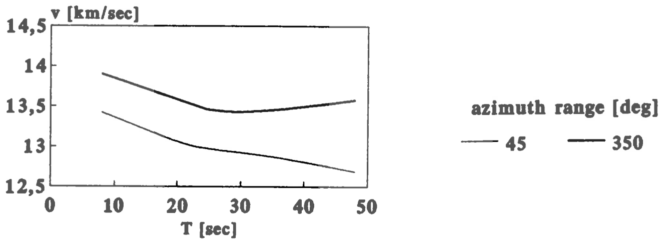

Fig. 5. Dispersion of P_{diff} for deep focus earthquakes (Fiji).

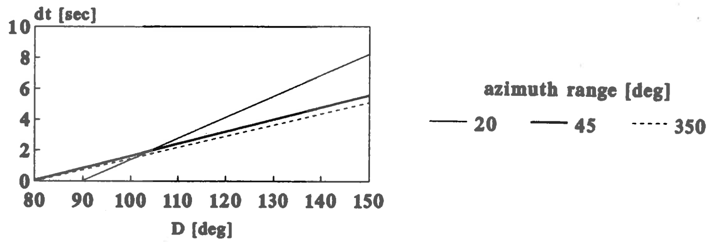

Fig. 6. Splitting of S_{diff}.

There are observations of diffracted waves at the inner core and also indications that whispering gallery waves propagating at the inner core boundary (Nakanishi, 1990, 1992).

CONCLUSIONS

The analysis of data has shown that for distinct regions at the CMB different velocity structure exist. This is represented by different frequency dependence of velocity of P_{diff} as well as by different S_{diff} splitting. Up to now the amount of analyzed data is to small to draw a picture about velocity's and velocity gradient's behaviour within the D"-layer. Nevertheless the possibility of using diffracted wave for studying laterally heterogeneous lowermost mantle is shown. Also the existence of non-ray geometrical waves at the inner core is demonstrated theoretically. Progress in seismological observations will give the possibility for using them in refining core models.

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ONE POSSIBILITY FOR STRUCTURAL HETEROGENEITIES LOCALIZATION IN THE EARTH CRUST BY THE METHOD OF SEISMIC NOISE TOMOGRAPHY

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INTRODUCTION

The paper is devoted to the investigation the of local heterogeneties in the medium applying the noise component of the seismic records by the seismic tomography method. This is one possibility to extend the knowledge about forming the nousy field connected to heterogeneties zones in the Earth crust.

PRINCIPLES OF NOISE TOMOGRAPHY METHODS (NTM)

Noise tomography applyies the noise-stop adaptive spatial methods for dividing the local heterogeneties (connected with noise radiation) by high-frequency part of the 3-C seismic data. It is supposed about the noise seismic sources that they are independend and radiate the polarizing spherical waves, which are coherent on spatial coordinates. The seismic noise of scattered waves is interference of waves of different nature, created by radiation or re-radiation of waves from local heterogeneties of the medium.

METHODS OF ADAPTIVE ESTIMATIONS

In this paper two adaptive methods with higher noise-stop ability Method of miniinum dispersion /MMD/ and Method of narrow-band polarizaton filtering /MNPF/ are applied [1,2].

MMD: Inasmutch the true polarization properties of noise are usually unknown, it is expedient for the model bean-form function to apply a coherent property of useful signal in the receiving source. This optimal criterion, which consists of minimization of the spatial dispersion of the results signal in the output group filter is used under the condition that the source radiation in a given directional vector passes through the filter without distortion.

MNPF:In this focusing transforms, suppression of projections of the coherent and uncoherent noise of seismic source components is made, if the direction of their polarization is different from the given signal direction (the uncoherent is suppressed by the unbaised polarization matrix estimate construction as well as by some additional procedures).MNPF is destined for a large seismic group data processing and it is fast (in calculation respect) and asymptotically efficacious. For comparision traditional method of continuous analysis of spatiallly distributed wave sources-method of maximum likelihood method (Capon estimation) (MLM)[2,3] is applied.

RESOLUTION CAPABILITIES OF THE METHODS. RECONSTRUCTION THE COMPLICATED IMAGE.

The optimal methods give a possibility for a qualitative reconstruction to the (K-1) uncorrelated sources in K channels of receiving (in the case of 3-C registration K=3*N). If there is a correlation, which is normally for near objects, the quantity of separation points will be less. The main problem in this case is the efficient suppression of the interference noise [2].

The results of synthetic image reconstruction (Fig.1) from 38 relative seismic scatters (distributed in depth 1 km in knots of the net step 0.1 km) by adding supplementary 10 % noise are shown. The plane registration receiving group consists of 16 points (8x2), linear size (2.1km X 0.7 km) and registration in real frequency range 75-175 Hz.(On Fig.1 are shown intensity and s/n for a/--MLM, b/-MMD, c/MMD(coord.filtering), d/-MNBPF(biased estim.), e/-MNBPF(unbiased est.)).

As shown the adaptive methods give a clearer and more stable image(the most essentialy qualitative one by MNPF) comparing to the MLM, in which,as shown, the pass characteristic is practically taken-off under conditions of intensity noise.

EXPERIMENTAL DATA ANALYSIS.

I. Borehole 3-C data analysis.

Vertical seismic profile (VSP) data from borehole in North Bulgaria are applied to detect the layers heterogenities zones by NTM [2]. The input 3-C data are received by 20 channels with 0.025km distance between obtained points and shot point offset 0.730km from the borehole.The velocity model applied in the analysis and results of the special polarization-frequency analyisis[4] show the avialability of different layer heterogeneties (Fig.2a). MMD in vertical sections in frequency band 45-55Hz with aperture size 0.5x0.5km by the step reconstrustion 0.1 km is applied.

The zones with maxima of P- and S- waves intensity scattering, connected to lithological changes zones in depths 0.3,0.5,0.9 km and 0.9-1.0 km are shown in Fig.2b. These results are confirmed by the geological information about the borehole space.

II. Surface 3-C array data analysis in Sofia seismic zone.

The circle seismic group with radius 60-90 km, consisting of 5 seismic 3-C stations was applied for registration of the spots explosions in Sofia seismic zone [2].The common tectonic map is shown in Fig.3a [4]. The aim of analysis is large scale pluton hetergeneties determination on depth by high-frequency part of records. MMD is applied for analysis together with Capon's estimation (MLM) for comparision. In the vertical sections for P- and S-intensity the map is given in Fig.3b .As shown MMD gives a possibility to increase the image accuracy comparing to MLM. Many zones with increasing scattering energy may be differentiated - depth 30-40 km and horizontal coordinates 40-50 km. For the horizontal sections of analysis on the 30,50 and 80km are detected zones connected with pluton bodies and burried faults(Fig.3c).

III. Surface 3-C array data analysis of microseismic noise around NPP "Kozloduy".

The data are obtained during the survey for design of a local seismological network around NPP "Kozloduy" (Bulgaria) [5].The microseismic noise (MSN) is consequently recieved at 15 points by 3-C digital recording in frequency band 0.2-25 Hz, sample rate 50 Hz and time duration 300s [5,(Fig.1)].Spatial characteristics of MSN are studied to locate the main structural elements that have an influence on energy of MSN field. The MNPF data processing is made in the vertical section for the frequency band 1-25 Hz with horizontal profile length (cross-section of the group in W-E direction) - 40points* 2km(step) = 80 km and down to depth 20points*2km(step)= 40 km.(aperture size in points - 40*20). On Fig.4 the P-energy scattering and quality function of transforms(called "ratio signal/noise") are shown. Maxima connected with large heterogeneous fault zone continuing in S-N direction are shown in Fig.4.

CONCLUSIONS

The main difference between noise tomography method and the traditional ones used for reconstruction of the medium structures is, that the NT does not request a source by wich the method of analysis to be built. The practical meaning of NT is the following: - a bigger noise stability and efficacy under a difficult seismo-geological condition, - NT gives possibility to determine noisy zones in the Earth crust, as well as detachment tectonic zones, searched and mapped underground hydrothermal sources, etc.

ACKNOWLEDGEMENTS

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Fig. 1 Reconstruction the synthetic images with different methods of NT: a/ MLM; b/ MMD; c/ MMD(coord.filtr.); d/ MNPF(bias.est.); e/ MNPF (unbias.est).

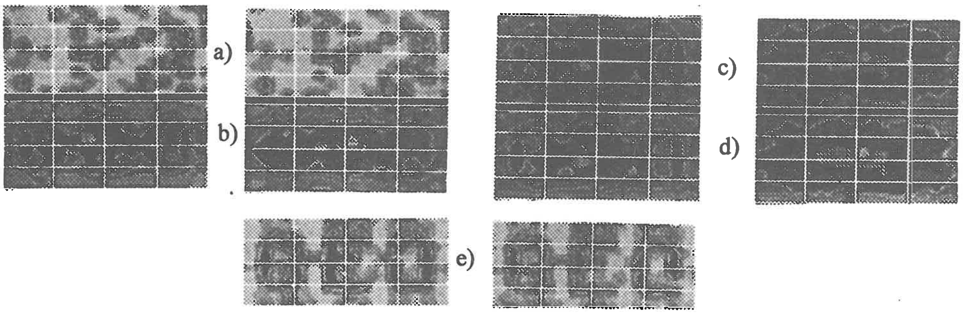


Fig. 2b Energy characteristics estimation (intensity and energy ratio s/n) for P-scattering by MMD.(VSP data).

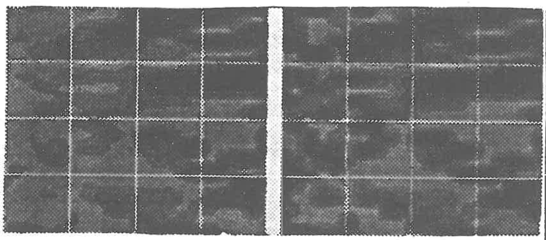


Fig. 2a Layer velocity chart and depolarization parameter variation for P-wave in vertical profile.

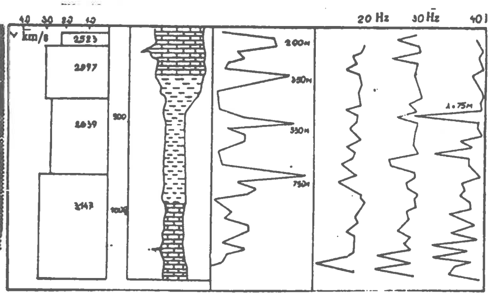
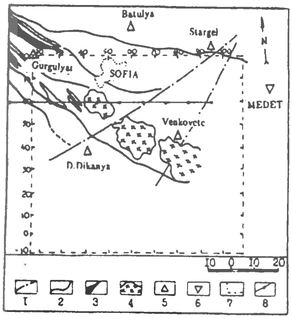
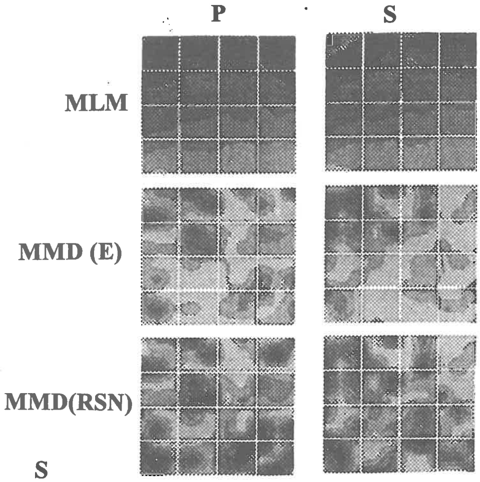


Fig. 3a Tectonic map of Sofia seismic zone (According to [4]).

Fig. 3b Energy estimation for P- and S-scattering by MMD in vertical plane (Sofia zone).





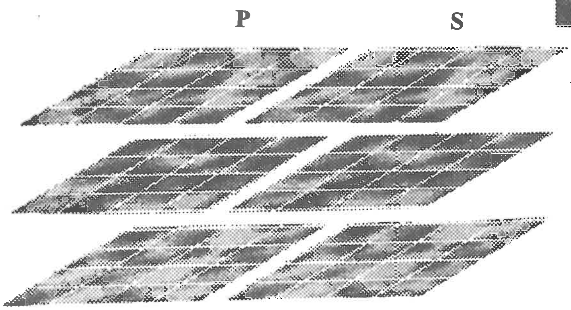
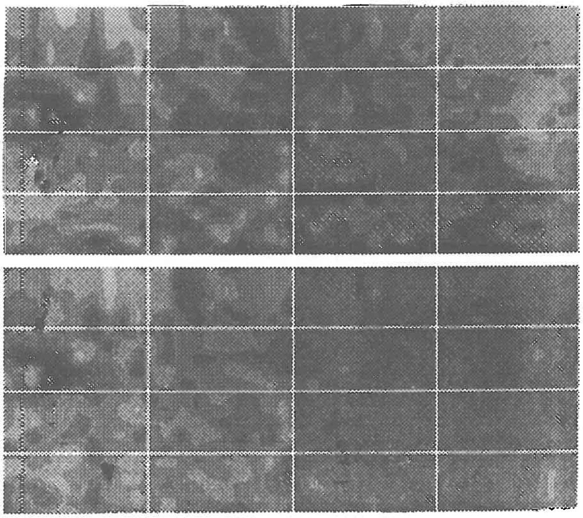


Fig. 3c Intensity estimation for P- and S- scattering by MMD in horizontal sections on 30, 50 and 80 km (Sofia zone).

Fig. 4 Energy characteristics estimation for P-scattering by MNPF in vertical plane W-E (Kozloduy NPP).



INVESTIGATION OF SPECTRAL AND SPATIAL MICROSEISMIC NOISE CHARACTERISTICS AROUND KOZLODUY NPP (BULGARIA)

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INTRODUCTION

The paper is devoted to a study of microseismic noise (MSN) characteristics around a nuclear power plant (NPP). During the survey for obtaining the most suitable places for local seismological stations around NPP "Kozloduy" observations of MSN at 25 different points were carried out. Short period three-component digital registrations (0.2-25 Hz) with time duration 300 s and sample rate 50 Hz are performed, consequently at 25 points.

EXPERIMENT DESCRIPTION

All observations were performed consequentially at points from the 50-km area south of NPP for the next periods 28.08-08.09.1991 and 07.10.1991-19.10.1991 (Fig.1). The equipment set for MSN recording and processing within Kozloduy NPP area was compiled at the Geophysical Institute of BAS with a standard company analog equipment from Teledyne Geotech and a digital equipment made in Bulgaria, ensuring necessary quality of collected information. All units, components, blocks and interfaces were metrologically assured.
The digital system for recording and processing of seismic signals was configured by standard components on the basis of PC AT 286/287 plus the necessary peripheral units. Analog signals are converted into a digital form by an 8-channel analog digital convertor [4] interfaced to the analog part of the system, ensuring level synchronization and synphase voltage protection.

METHODS OF ANALYSIS

Method of Noise Tomography (NT) is one of the MSN analysis methods giving the spatial characteristics of seismic noise. In NT the noise-stop spatial focusing transform with additional adaptive polarization filtering procedure is applied [1,2].
The following model of MSN is suggested: the different MSN sources are independent and radiate the polarizing spherical waves, which are coherent on spatial coordinates [2]. The microseismic noise of scattering waves is interference of waves with different nature, created by radiation or re-radiation of waves from local heterogeneities of the medium. The main problem of the analysis is in the intensity estimation of unknown sources and their spatial distribution reconstruction [1].
The method of narrow-band polarization filtering (MNPF) is one of the NT methods[1,2]. In the present work MNPF for estimation of the spatial distribution of MSN sources around NPP Kozloduy is applied. MNPF uses the same optimal criteria as Capon method (Maximum Likelihood method) [3] and additional optimization criterion by the minimum mean-square method and it gives suppression of polarization noise in the signal direction[1,2]. For the large scale of receivers MNPF is fast and efficient.
The intensity estimation of the MSN sources for P- and S- type of wave polarization on the MNPF base is calculated by the following formula:

$$E(r)=Spur\{\tilde{P}(r)S^{-2}(r)\tilde{P}(r)\} \qquad (1)$$

where $\tilde{S}=\tilde{P}+\tilde{R}$; $\tilde{P},\tilde{R}$ - polarization matrix estimations for the coherent and uncoherent part of the process; r - analyzed point.
The following expression is applied as a quality function of analysis:

$$\tilde{Q}(r)=1/(2-\hat{Q}(r)) \quad (2)$$

where $\tilde{Q}(r)$- maximum value of the coherent characteristics [1,2].

SPECTRAL CHARACTERISTICS OF THE MSN

Each 3-C record after digitizing consists of 32568 samples with a sample rate 0.010 sec and time length 325.68 sec. Examples of the time schedule of the components in time interval 0-120 sec are shown on Fig.2. Records are divided in to 2 parts - I part 0-162.84 sec and II part 162.85-325.68 sec. For each of these parts the input signal is scanned by 16384 points rectangular window and FFT spectrum with standard Fourier algorithm is calculated [4]. Output spectra have 8193 frequencies with 0.006 Hz step in the 0-50 Hz range.

The noise energy distribution is presented for every frequency by the root mean square value (RMS) of the ground surface oscillation velocity in the 0-50 Hz range. FFT spectra, the maximum RMS and respective frequency for three observational points are shown on Fig.3. Maxima of RMSv are distributed in 1.0-10Hz range with a dominant characteristic range 2.4-8 Hz.

After classification the RMS spectra of the observational points for every microseismic noise level, only those points with obtained low level of the local effects (wind, artificial effects) are chosen.

Since the registration in all points is not simultaneously, for the following spectral a analysis common RMS spectrum for all 15 chosen 3-C points are calculated. Erms for all channels (NS,Z,EW) recapitulated in the frequency range 0-50 Hz are shown on Fig.4. The main energy of the MSN is concentrated within the 1-20 Hz range.

SPATIAL CHARACTERISTICS OF THE MSN

MSN spatial distribution are calculated in vertical and horizontal profiles of analysis in a radius up to 50 km from NPP "Kozloduy". The main aim of the analysis is a detection of main "noisy" zones, and intensity estimation from their common MSN field. 15 3-C ones from all the quantity of receiving points are selected . The distance between points varies in 2-80 L range (L - mean wave length, L == 650 m)

In the analysis a plane-parallel velocity model with horizontal boundaries and without attenuation is applied. The concrete velocity model is shown in Tabl.1

Table 1. Local velocity model around NPP Kozloduy [5].

Depth to the upper boundary of layer (km)	Vp (km/s)	Vs (km/s)
0	5.7	3.4
18	6.6	3.8
35	7.9	4.5

The vertical section W-E (Fig.5) is calculated for the II part of time records for P,SV and SH waves with the following parameters: unbiased estimation; steps of analysis -dX=3L (X=0-60km); dZ=3L (Z=0-40km); frequency range 1-20 Hz with step 0.3 Hz; window length - 51 samples; window type - rectangular; without absorbtion correction. Fig.5 presents the intensity of scattering according to Eq.(1) and the map of ratio signal/noise according to Eq.(2). At depths 35,39 km around W- and E-borders of V-profile the maxima of intensity connected perhaps with the structural heterogeneity of the medium are shown .

The N-S V-profile of analysis (Fig.6) is calculated by the same processing parameters as for W-E V-profile. The significant increasing of intensity of scattering in depths 10, 25 and 30 km is connected with more heterogeneous zones continuing in W-E direction.

For horizontal planes the scattering intensity by P-waves for depths 1,4,6 and 8 km in processing window X - 0-60 km Y - 0-40km is calculated (Fig. 7). The maxima of intensity for all the depths around W and SE boundaries of processing H-window are shown. The central zone of the analyzed region has a low level of intensity.
The maps of ratio S/N for all sections gives information about the quality of reconstruction images and changes in 2-5% range.

CONCLUSIONS

The obtained results about MSN frequency and spatial characteristics show an absence of large heterogeneities structures in radius up to 50 km from NPP "Kozloduy". All available geophysical information about the investigation region is consistent with our conclusion concerning the absence of large scale horizontal heterogeneities near NPP. More detailed and precise information about MSN can be received after bulding up the local seismological network around NPP.

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Fig.1 Survey map arround NPP"Kozloduy".

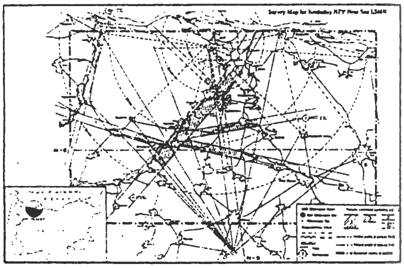
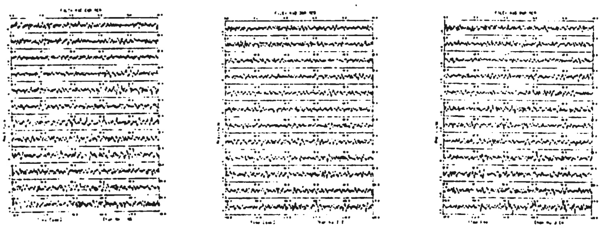


Fig.2 Example of the time schedule of the components in time interval 0-120 sec.



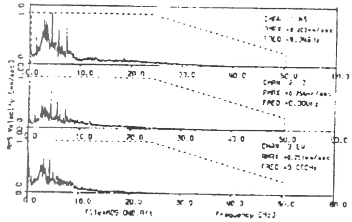


Fig.3 RMS FFT spectra for one observational point .

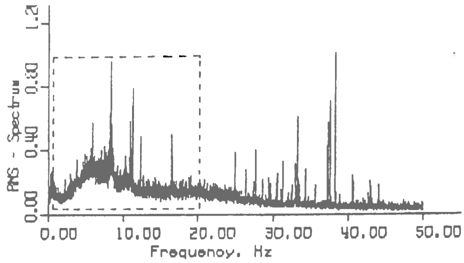


Fig.4 RMS FFT spectrum for all channels (NS,Z,EW) recapitulated in frequency range 0-50 Hz .

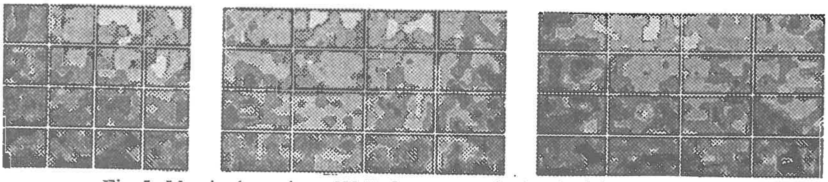


Fig.5 Vertical sections W-E for part II (P,SV,SH) by MNPF

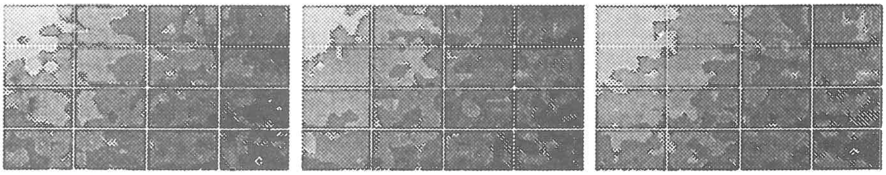


Fig.6 Vertical sections N-S for part II (P,SV,SH) by MNPF

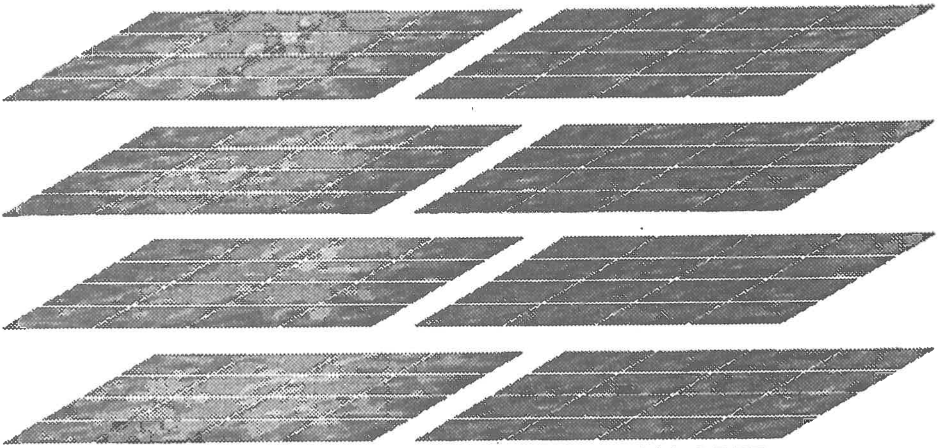


Fig.7 Horizontal sections H=1,4,6,8 km for part II (P) by MNPF

DETECTION CAPABILITY OF MLR STATION OF THE ROMANIAN NETWORK

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During April 22 - June 2, 1991 Romania participated at the full-scale phase of GSETT-2 (Group of Scientific Experts' Second Technical Test), the international experiment of seismic data acquisition, exchange and processing, organized by the Ad Hoc Group of Scientific Experts to Consider International Cooperative Measures to Detect and Identify Seismic Events, established by the Conference on Disarmament. The purpose of GSETT-2 was to test initial design concepts for a modern global system for international seismic data exchange (CD/1144).

During the experiment, data including parameters to be used to locate seismic events and determine magnitude (arrival times, maximum amplitudes and associated periods, back azimuth, angle of incidence, slowness, level of rectilinearity) and the corresponding waveform segments were provided daily, for every recorded seismic event, according to specific procedures (CRP/190). The used global network consisted of 60 stations located in all the continents (48 single-site stations and 12 seismic arrays); their data were analysed in the National Data Centers (NDCs) operating in each of the 34 participating countries. The data were sent to the Experimental International Data Centers (EIDCs) in Canberra, Moscow, Stockholm and Washington, where all the information provided by a global network was processed. A variety of modern international communication links were used for NDC - EIDC and EIDC - EIDC connections.

The products of the data analysis and processing in the EIDCs were bulletins including the locations obtained for each seismic event (based on the information provided by the global network) and all the phases associated to the locations, as well as, the NDC locations (based on local or regional networks) and the unassociated phase list.

The Romanian seismic station which participated in this experiment is Cheia - Muntele Roşu (MLR), located at 45.49°N, 25.94°E. It belongs to the national telemetered seismic network and it is equiped with short period S-13 instruments (3 components, the vertical one with two gain channels), with continuous digital and analog data acquisition (Oancea and Oncescu, 1991).

During the 42 days of experiment, Romania NDC provided data on 345 phases, identified on the digital recordings of MLR station. 70% of them were associated to 137 event locations in the bulletins. The epicentral distances of these events, relative to MLR station, are up to 153.9°. The most distant recorded events to which MLR contributed phases are two underground nuclear explosions conducted in Tuamotu Islands (May 18 and 29, 1991, m_b=4.7 and 5.0).

Fig.1 presents a plot of the magnitude of the recorded seismic events versus their epicentral distance relative to MLR station. It is noticeable that the detection capability is characterized by a threshold of about m_b=2.0 for regional events ($\Delta<10^\circ$). As regards the teleseismic events, MLR station recorded events with $m_b>3.0$ for $10^\circ<\Delta<50^\circ$ and with $m_b>4.0$ for greater epicentral distances.

We remark the Caucasus event (April 29, 1991, m_b=6.6) and its aftershock sequence which occured during GSETT-2. The bulletins of the experiment includ locations for 115 earthquakes in the sequence; MLR station (Δ_{MLR}=12.9°) reported data for 36 of them (m_b=3.2-6.6).

The detections of MLR station cover the whole azimuth domain, with a maximum in the direction corresponding to the Caucasus sequence and local earthquakes in Vrancea region (θ=280°-340°) (Fig.2).

ROM NDC reported 111 phases for 58 local events (earthquakes and quarry blasts) which occurred during the 42 days of experiment on the Romanian territory (Oancea and Popescu, 1991). For 17 events, we also reported locations obtained using the national seismic network data. These events have Δ_{MLR}=0.2°-2.1° and duration-based magnitudes M_D=2.1-4.5. Only 11 of them could be relocated by the EIDCs, using data from other stations of the global network. This fact and also the including of many phases (reported by MLR as local ones) in the unassociated phase list are due to the lack of participating stations in the immediate neighbourhood of our borders and especially of Vrancea region. The nearest participating station was LJU (Δ~8°).

Many local events occurred in the most active seismic area on our territory, Vrancea region. It is characterized by the occurrence of intermediate depth earthquakes, as well as normal depth ones. MLR station is located in their epicentral area and it is a station with high sensitivity and low noise (Fig. 3), which records a lot of small local events (sometimes unrecorded by other Romanian stations). This explains the large number of MLR phases (around 30%) which were not associated to located events, in the bulletins elaborated by the EIDCs.

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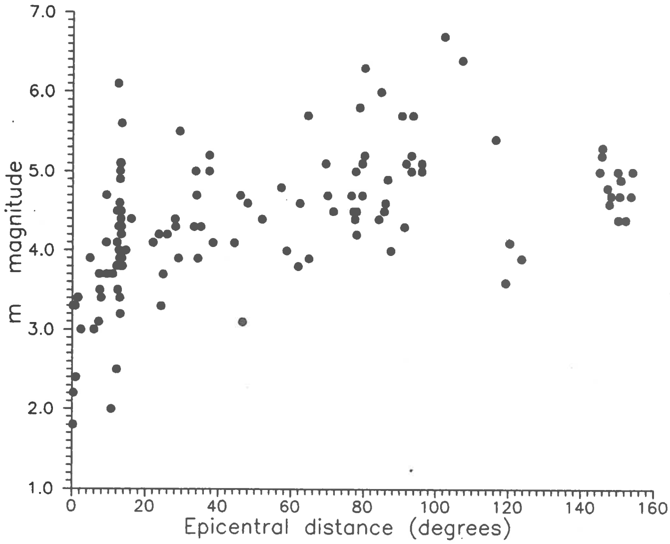

Fig. 1 – Magnitude of the recorded seismic events versus epicentral distance to MLR station

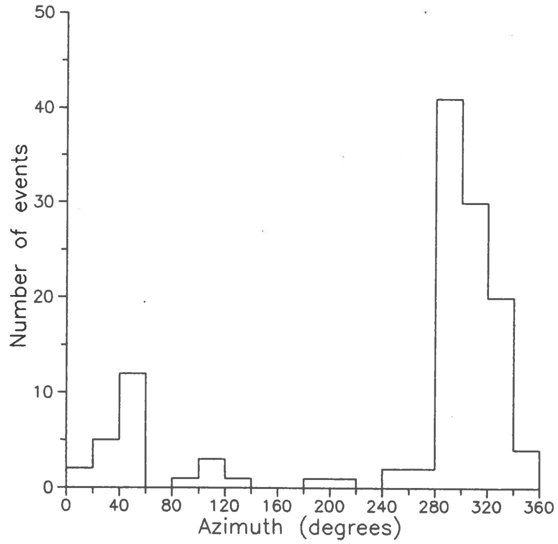

Fig. 2 – Azimuthal distribution of detections

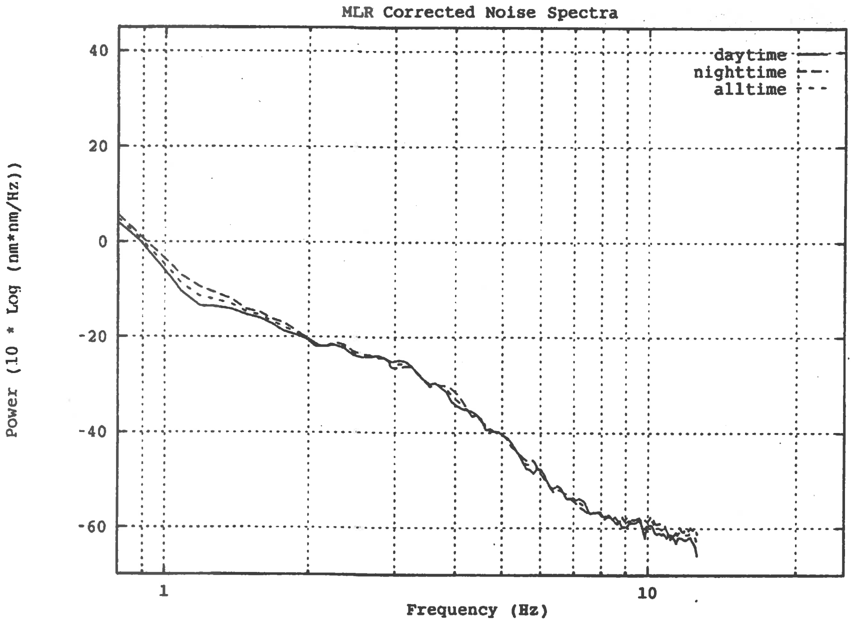
MLR Corrected Noise Spectra
daytime
nighttime
alltime
40
20
0
-20
-40
-60
Power (10 * Log (nm*nm/Hz))
1
10
Frequency (Hz)

Fig. 3

SOME ADDITIONAL RESULTS ON MAGNITUDE DETERMINATION PROBLEM IN THE PRACTICE.

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INTRODUCTION

The current presentation aims to show some recent results on magnitudes and other dynamic parameters of earthquakes by standard and TCHISS instruments (frequency-selective) in comparison with so named "spectral magnitude" developed in (Duda et.al.1992).

The spectral magnitude problem was discussed in prof. S.Duda and T.Yanovskaya IASPEI working group and on its advice the previous investigation (Kondorskaya, et.al.1993) were extended. In particular the addition data of the earthquakes located in different regions on different epicentral distances were included.

MATERIALS AND METHOD

In addition to the data for Armenian upland and adjacent regions, (Kondorskaya et.al.1993) the data of Iranian and Chinese earthquakes were used, all toqether 29 earthquakes.

For magnitude calculation the preliminary spectral calibrating functions after (Nortman and Duda,1983) as well as those calculated on the basis of IASPEI 91 velocity model shifted to the level corresponding to HMS (Duda et.al., these Proceedings) were used. The calibrating functions are presented in the Fig.1.

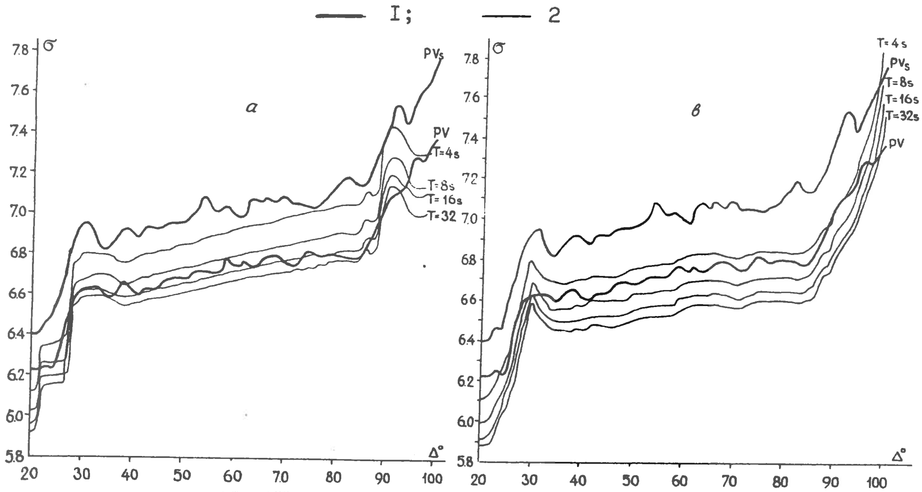

Fig.1. Comparison HMS calibrating function (1) with so named "spectral magnitude"calibrating function (2)

a) After Duda et.al.(these Proceedings)with IASPEI-91model.
b) After Nortman and Duda (1983) with Q model.

On basis of these calibrating functions magnitude spectra were constructed by using TCHISS records for each earthquake used.

The description of TCHISS station, it's amplitude-frequency characteristics and method of magnitude spectra constructing see in (Kondorskaya et.al.,1993).

RESULTS

The examples of the magnitude spectra for earthquakes of the 3 region selected (Armenian upland, Iran and China) are shown in Fig.2.

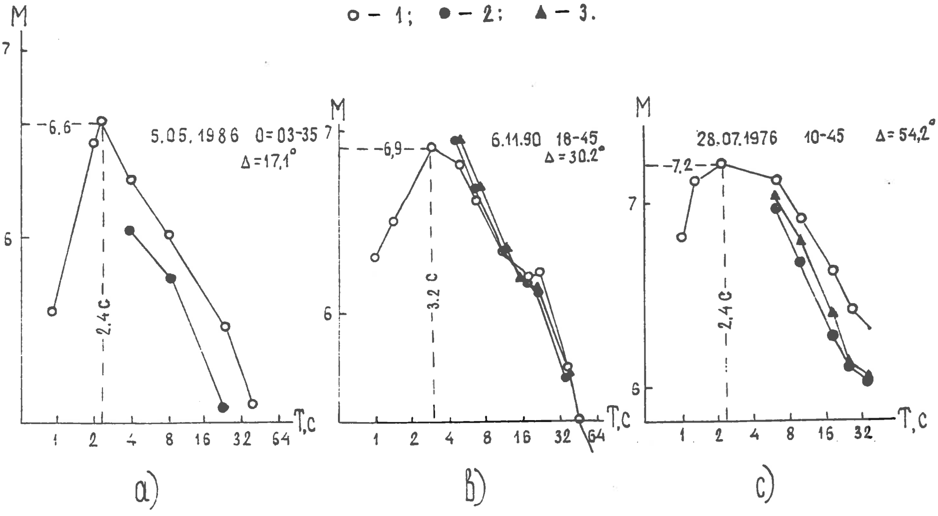

Fig.2. Magnitude spectra of P waves with different calibrating functions: 1 - HMS (Christoskov et.al.,1991); 2 - spectral (Nortman and Duda, 1983); 3 - spectral (Duda et.al., these Proceedings).
a) Armenian upland and adjacent area,
b) Iranian region,
c) China region.

It is noteworthy that magnitude spectra show no significant dependence upon the calibrating functions used.
However, for epicentral distances 15-20° and more than 50° the spectra magnitude curve calculated on basis spectral calibrating functions lies lower, while for those of 25-30° it lies higher or coincides with the curve obtained on the basis of HMS.

Taking into account general reguliarities of magnitude spectra, the spectral magnitudes (M*) for the each earthquake were calculated. The values this obtained are presented in the Fig.3 together with magnitudes MPV (USSO, Russia) and Mb (ISC).

As can be seen the spectral magnitude values (M*) differs no significantly from MPV while the values M* and Mb are very scaterring and deviation in average is approximately about 0.8-1.0 unit of magnitude.

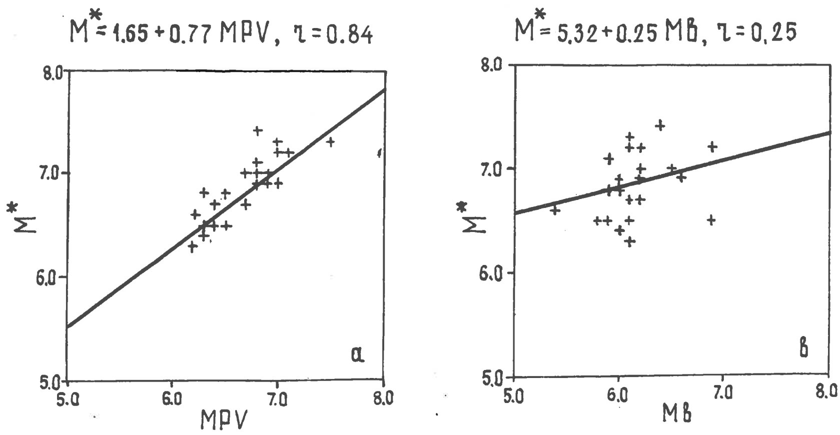

Fig.3. Relationships between different magnitudes.

a) MPV= f(M*),
b) Mb= f(M*),
r - coefficent of correlation.

For the further develoment of earthquake quantification it is significant to define the period-dependent calibrating functions especially for short period seismic radiation and include into interpretation digital data of several stations located in different azimuth.

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REGIONAL PECULIARITIES OF AN ENERGETIC VALUE OF THE BLACK SEA EARTHQUAKES.

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Statement of a quastion.

When calibrating the earthquakes according to an energetic class and a magnitude by usual methods, principal difficulties occur, because of changing a wave picture structure when passaging from small distances in an epicentral zone to teleseismic ones across an intermidiate zone with extremely unstable, regionally changable peculiarities of amplitude curves. As a result, there are different magnitude scales for small and teleseismic distances. In attempts to prolong these scales into an intermidiate range of distances, the local scales occur which are not connected with scales of adjacent regions. It makes difficalties for obtaining the uniform material for quantitative characteristics of seismicity, in particular, in the Black Sea bassin and the adjacent areas. The Crimean local earthquakes are classified according to an energetic scale (Pustovitenko, Kulchitsky) and those of the Caucasus, a neighbouring region, according to (Rautian).

For nearby earthquakes (Δ<2000 km) the magnitudes M_{LH} are estimated by the Crimean stations data, for deep sources of the Vrancea zone an energetic class is estimated by the scale [Раутиан]. It's known that even for the most stable scale M_{LH} a special correction system of distorsions for the surface waves is necessary at the expense of the inhomogeneities of the Black Sea. As for the Vrancea sources, it makes sence to estimate only a magnitude by the body waves, m_b, m_{pv}. However, it is very difficult to obtain calibration damping curves of the P and S waves by a typical method in the nearest zone of the Crimea (Δ<2000 km).

Damping curves of the body waves.

The Study of the damping waves by a rationing method is the only possible way in the cases, when there is no a station profile and is more stable than a rationing method with the help of a magnitude and an energetic class, defined with a considerable error. The records of the seismic station "Simferopol" (SMF), made by a short-period SH and a long-period SKD seismographs for the period of 1966-1980, have been used.

There have been processed more than 150 earthquakes of the Black Sea, Turkey, Caucasus, Carpathians, Yugoslavia, the Aegean Sea and the Sea of Marmora, Iran with the epicentral distances R=50÷2000 km in the magnitude range M=3.2÷6.5. Construction of the amplitude curves as a function of a distance was conducted by the methods discribed early for the Crimea [Pustovitenko, Rautian]. Summary envelope SH and SKD -codes for the nearist zone and a coda level as the travel time t_c= 500s were used. The fixed values were calculated:

$$a_s, a_p^{SH} = \frac{A_{S,P}^{SH}}{A_{500}^{SH}} \quad ; \quad a_S, a_P^{SKD} = \frac{A_{S,P}^{SKD}}{A_{500}^{SKD}}$$

where $A_{S,P}^{SH}$ and $A_{S,P}^{SKD}$ - amplitudes of compressional S and longitudinal P-waves, measured according to the records of a short-period SH (SKM) and a mean-period SKD seismographs. A_{500}^{SH} and A_{500}^{SKD} - code amplitudes at the financed time t=500 by the records of the SH and SKD seismographs, correspondingly.

The damping curves of the body P and S-waves with a distance (R) $a_s^{SH} = f(R)$; $a_s^{SKD} = f(R)$; $a_p^{SH} = f(R)$; $a_p^{SKD} = f(R)$ differ by the large scattering of the experimental data (fig.1) relatively of a theoretical dependence of a type:

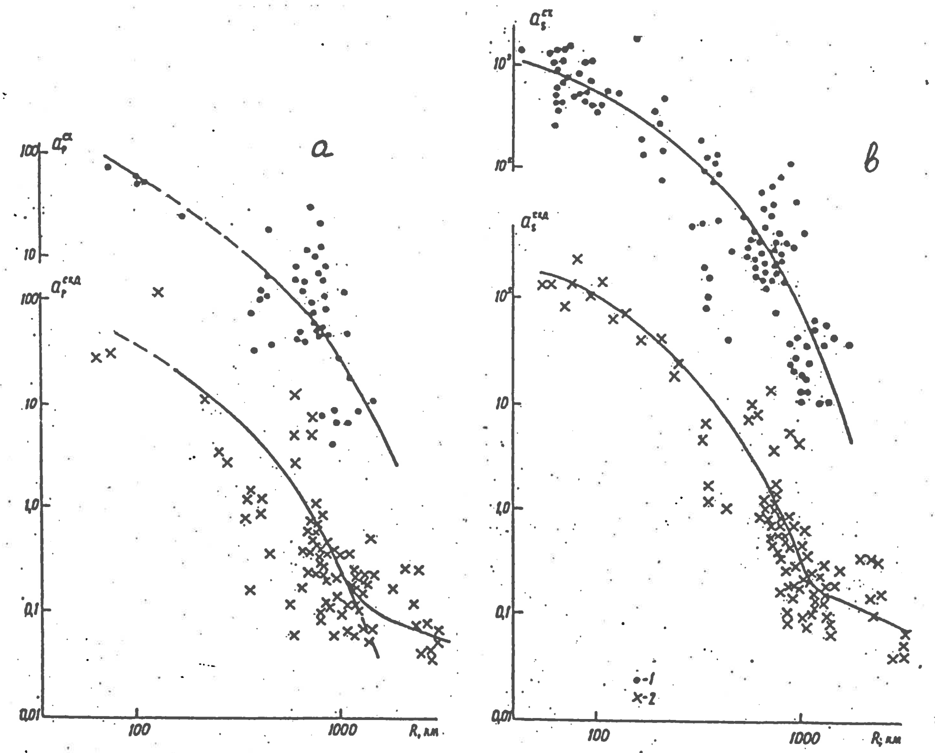

Fig.1. Damping curves of the longitudinal P (a) and the compressional S (b) waves by the records of seismographs: 1) short-period SH; 2) mean-period SKD. Station "Simferopol" (SIM).

$$A(t) \simeq t^{-\gamma} \exp\left(-\frac{\pi f t}{Q}\right).$$

Majority of the points with deviations refers to the earthquakes of the eastern sector (the Caucasus, Turkey). This may be connected with both the considerable absorption of waves along a source-station trace and the minimum of a function of radiation trend from a source.

In the epicentral distances range up to 1000 km the fixed amplitudes of the S and P-waves damp according to the law R^{-n}, where n_s=1.9, n_p=1.7 by the records of SH, and n_s=2.5 and n_p=2.1 by the records of SKD seismographs. In the distance range Δ=1000÷2000 km the fixed amplitudes damp weakly, forming a "step" in the plot. Obtained by such a way, the damping curves and the law of their falling down were assumed as a basis of a calibration function for a magnitude classification of earthquakes by the P-and S-waves.

Magnitude classification.

The next data are necessary for the construction of magnitude definition nomograms by the body waves: 1) a law of damping waves; 2) correlative relations between magnitudes and amplitudes under the fixed hypocentral distances R=const. R=1000 km has been chosen for the areas, where there were a majority of the direct experimental data. The last values A_P and A_S were found by a method of extrapolation of the values a_p and a_s up to R=1000 km, and by the amplitudes recounting: $A_S=a_s \cdot A_{500}$; $A_P= a_p \cdot A_{500}$.

Correlative relations were calculated for the magnitudes m_{pv}^{SKM} and m_{pv}^{SKD} by the orthogonal regression method:

$$\lg A^{SH}=0.75\, m_{pv}^{SKM}-3.45\,, \qquad \rho=0.99 \qquad (1)$$

$$\lg A^{SKD}=1.27\, m_{pv}^{SKD}-6.73\,, \qquad \rho=0.99 \qquad (2)$$

$$\lg A^{SKD}=1.99\, m_b -10.2\,, \qquad \rho=0.99 \qquad (3)$$

Calculations were carried out according to the mean values in the interval by the magnitude ΔM=0.5 with a step 0.5.

By the relations (1-3) and a family of the damping curves (fig. 1,2) the corresponding nomograms for the magnitudes m_{pv} and m_b estimation were constructed for the practical usage in the range of epicentral distances Δ=20÷2000 km.

The magnitude scales m_{pv}^{SKM} and m_{pv}^{SKD}, constructed by the reliable calibration curves with the application of rationing to a seismic coda, are recommended to use when interpreting the earthquake records of the nearest zone of the Crimea in the wide range of magnitudes, including the weak earthquakes, too.

Amplitude corrections.

It was noted, that separate seismic active zones give systematic overstating $+\Delta a_{s,p}$ or understating $-\Delta a_{s,p}$ of the body wave amplitudes a_i by the records of the Crimean stations in comparison with a theoretical curve of approximation. Thus, for the earthquakes of Iran, Kazahstan and the Mediterranean Sea the

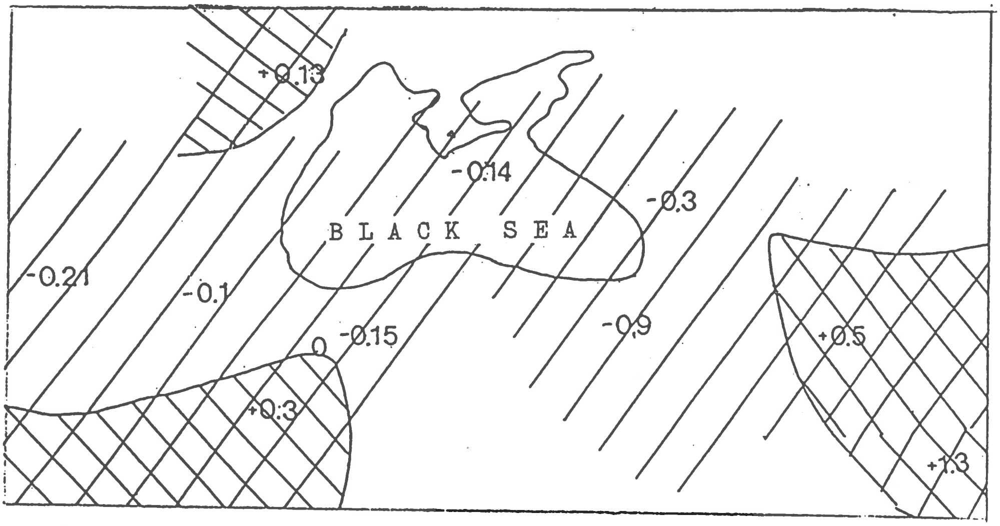

Fig.2. Spatial distribution of deviations of a_s- and a_p-values from the approximate theoretical curve.

deviations Δa_s^{SKD} make up +0.8÷1.3.

Negative values Δa_s were obtained for the zones of the Caucasus, Black Sea, Yugoslavia, and absolute values of correction (by a modulus) were much larger for the Eastern Turkey than for the Western one, i.e. Δa_s^E=-0.88, Δa_s^W=-0.13, correspondingly.

Spatial distribution of deviations of the fixed values is shown in the fig.2.

Registration of the regional corrections allows to reduce errors when defining the magnitudes m_s, m_{pv} by the developed nomograms for the magnitude estimation of the Black Sea and it's vicihity.

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LOCAL MAGNITUDE CALIBRATION BY USING CODA WAVE AMPLITUDES

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INTRODUCTION

Seismic coda waves contain useful information regarding both source and propagation. The study of coda characteristics (e.g., amplitude, envelope, spectral content) emphasizes their dependence on seismic moment, attenuation, site response, etc. Since the coda amplitude is proportional with the seismic moment (Aki and Chouet, 1975), the coda waves offer the possibility to determine an energy calibrated magnitude scale by direct measurements.

Recently, Trifu and Radulian (1991), established a locally calibrated moment magnitude scale for Vrancea events (M_L=2.5-5.0). Their magnitudes are computed from the time difference between the first P and S wave arrivals and total record duration, and they properly account for the focal depth (h>60km). A linear moment-magnitude dependence is obtained over the whole magnitude range, the seismic moment values being determined from low frequency spectral levels. The present study offers an alternative calibration of these magnitudes by using the seismic moment-coda wave amplitude proportionality hypothesis. The independence of the two approaches allows both to verify the local magnitude scale, and to test the above proportionality hypothesis in case of Vrancea intermediate depth earthquakes.

METHOD AND DATA

For a particular seismic region, Aki (1969) and Aki and Chouet (1975) noticed that the shape of the coda wave envelope recorded at a station, logA(logt) is independent on distance and azimuth to the focus, as well as on earthquake magnitude. Same authors found that the coda amplitude value is linearly dependent on seismic moment. Taking into account that $\log M_0 \propto M$, Aki (1987) obtained:

$$\log A = aM_L + b\log t + c \qquad (1)$$

Radu et al. (1983) studied the coda envelope as a function of time for Vrancea intermediate depth earthquakes, emphasizing its independence on source-station geometry and source magnitude.

For the same events, Trifu and Radulian (1991) found:

$$\log M_0 = 1.0M_L + 17.4 \qquad (2)$$

Thus, relation (1) is likely to be applied in Vrancea, providing a powerful check of the energy calibrated local magnitude scale for this region. The above a, b, c coefficients are estimated through a multiple regression alghorithm.

Analog recordings of the seismic station MLR (Cheia) have been used for 209 Vrancea earthquakes (h>60km; M_L=2.3-5.6) occured between 1981 and 1986 (S13 velocity transducer, vertical component, high magnification channel), whose joint locations were available (Oncescu, 1986). Peak-to-peak amplitudes, in mm, are taken by direct reading (Oancea and Bazacliu, 1991). For the considered magnitude domain, the recorded frequency content lies mainly betweeen 1-10Hz. In this bandwidth the instrument response has a fairly flat response in amplitude (velocity), which consequently allows us to neglect the instrument correction up to a constant (gain value). The amplitudes are measured at a time step of 5s, excepting for the smallest magnitudes (M_L<3.0), for which the time step is reduced to 2s. We selected only the earthquakes and time domains giving rise to linear dependences logA=f(logt). Some exemples are shown in Fig. 1. Thus, there are avoided both small times ($t<2t_S$), because the wave envelope variation significantly changes when approaching the S wave arrival, and large times, mainly for larger magnitudes, when a spreading intensity variation in coda is noticed (Rautian and Khalturin, 1978).

RESULTS AND CONCLUSIONS

A number of 209 events are retained according to the previous criteria. The multiple inversion leads to:

$$\log A=(1.10\pm0.01)M_L-(2.59\pm0.04)\log t+1.18 \qquad (3)$$

A series of factors affecting the coda wave amplitude at a site, e.g. focal mechanism, attenuation, geometrical spreading, are not considered in the inference of the above relationship. However, the Vrancea intermediate depth earthquakes have generally an underthrusting mechanism on a nearly vertical fault plane, and thus, the individual amplitudes at MLR can be considered, to a first aproximation, in good agreement with an average mechanism.

Due to the relative large extent of the focal zone, it is reasonably to consider that the dependence $\log A(M_L)$ differs with depth mainly. To have an estimate of the depth influence, separate regressions were made on two depth domains, h=60-115km, and h>115km, respectively. The corresponding values of the a coefficient are 0.99 and 1.12. This rather small variation of about 10% is expected since the M_L scale, as introduced by Trifu and Radulian (1991), accounts very well for the earthquake depth.

Two conclusions can be drawn from this study: (a) the value of the moment-magnitude coefficient in equation (2) previously obtained by Trifu and Radulian (1991) is well reproduced in this work by another method; (b) a local magnitude relationship can be derived from (3), based on the coda wave amplitude recorded at a single station (MLR):

$$M_L=0.91\log A+2.36\log t-1.08 \qquad (4)$$

Evidently, to improve its reliability, other stations should be further considered.

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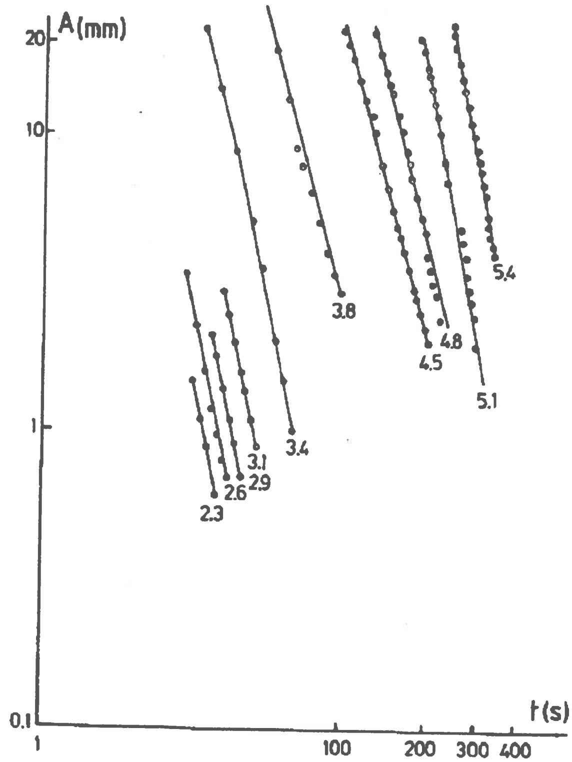

Fig. 1 - Coda amplitude dependence on time for earthquakes of different magnitudes

An Improvement to HYPO Programs. Location on Vertically Inhomogeneous Media

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Introduction

Regional seismic networks widely use HYPO71 (or HYPO-like) programs for routinary hypocentral location. We present an improvement of the HYPO71 program (Lee and Lahr, 1975). It has been adapted to perform location on vertically inhomogeneous media in such a way the improved program, called HYPOTAU, is operated in the same way as the older version. This makes no difference for the user and facilites a quick implementation. HYPOTAU has been tested and shows good performances, even for events located outside the network or in absence of S-wave arrival times. We present an aplication to earthquakes located on the catalan coast, on the NE of the Iberian peninsula.

Theoretical aproach

Improvement of HYPO-71 program has been done by substitution of the original subroutine TRVDRV (Eaton, 1969) for the calculation of the seismic wave travel times. As TRVDRV uses a homogeneous layer horizontally stratified model of earth, the new one calculates travel times for waves propagating throught layers where velocity is allowed to vary linearly with depth (vertically inhomogeneous layers) on a horizontally stratified earth. TRVDRV calculates the seismic wave travel times and derivatives in a geometrical way, whereas the new one follows the method proposed by Buland and Chapman (1983) based on the stationary points of the called Theta function defined as

$$\theta(p, x) = \tau(p) - px \qquad (1)$$

where $\tau(p)$ is the intercept time, p the ray parameter and x the source-receiver distance. The phase arrival time at a seismic station is stated as

$$T = \theta(p_0, X) \qquad (2)$$

where p_0 is defined as

$$\left.\frac{\partial\theta(p, x)}{\partial p}\right|_{x=X} = 0 \qquad (3)$$

Travel times are obtained from equation (2) whereas solutions of equation (3) provide us with exact horizontal derivatives. Vertical derivative is numerically approached.

Location test and aplication

HYPOTAU has been tested in two different ways. First, we generated synthetic events for arbitrary seismic networks of 10 stations with aleatory distribution around a central point and in a radius R. Several distances from the event hypocenter to the center of the network were tested as well as different hypocentral depths for the events or different velocity models (both homogeneous and inhomogeneous). Fig. 1-left gives an example of station-epicenter distribution. No noise was introduced in the synthetic arrival times because our goal was to test the capability of the program to calculate the wave travel times. As location algorithm is not changed, we assume it performs properly. Because hypocentral coordinates are known, exact errors for every case are calculated. For homogeneous media hypocentral error behaves as HYPO71 does. For inhomogeneous media we cannot compare the errors, but epicentral error does not exceed 6 km for networks of radius $R = 90$ km and distances from epicenters to the center of the network $d = 450$ km. Figs. 1-right show hypo and epicentral real errors.

Second test of the program was made by location of two explosions at sea, near the coast of Catalonia, which hypocentral parameters were known. Locations for different velocity models show absolute epicentral errors smaller than 1.6 km and origin time errors smaller than 0.7 s. Fig. 2-left shows, for one of the events, the recording stations and explosion location. Fig. 2-right shows epicentral locations for different used models.

Aplication of HYPOTAU has been performed to relocate a set of earthquakes ocurred during years 1984 to 1990 near the coast of Catalonia, in the Northeastern part of the Iberian peninsula. Hypocenter coordinates and arrival times have been published in the bulletins of the *Servei Geològic de Catalunya*, SGC. Relocation of the events using the same velocity model than the SGC does not show any difference with the original location (fig. 3). Other models have been use and only minor differences appeared. HYPOTAU shows clearly a greatest stability than HYPO71 in the epicentral solution when only P-waves are used (fig. 4).

Discusion and conclusions

HYPOTAU, an improvement of HYPO71 program that allows it to locate seismic events in vertically inhomogeneous media has been presented. Test of the program with synthetic and real events and different velocity models shows HYPOTAU locations are reliable. It improves clearly the capabilities of HYPO71 when only P-waves are used.

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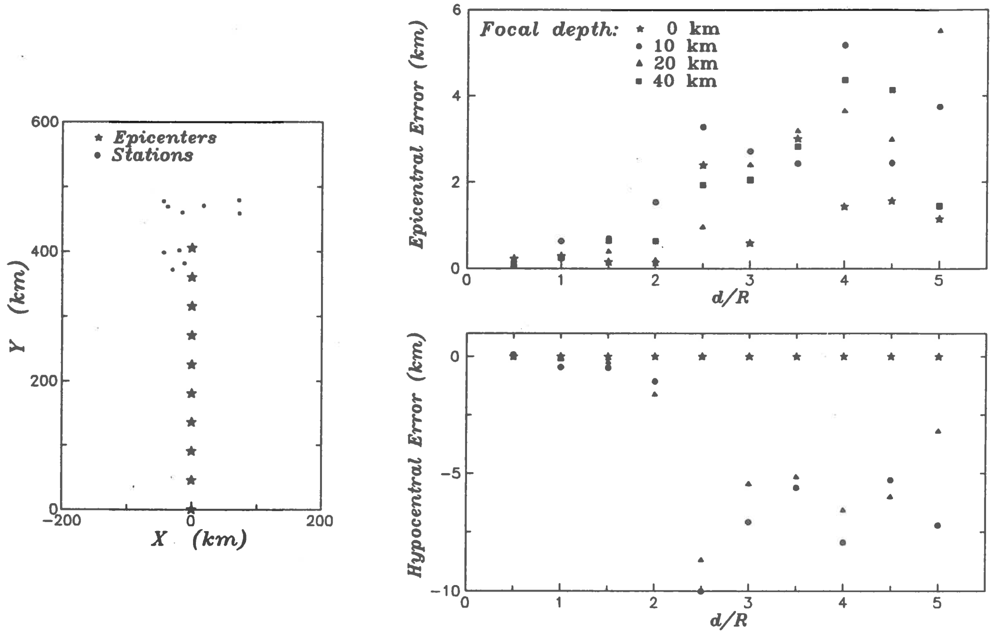

Figure 1: Left- Distribution of recording stations and epicenters for a test of HYPOTAU. Right- HYPOTAU real errors for different epicentral distances and focal depths.

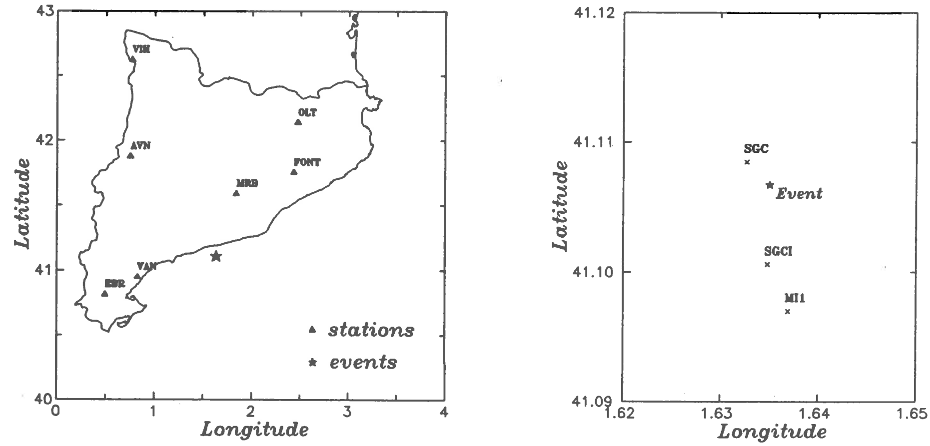

Figure 2: Recording stations and explosion used for the test of HYPOTAU and detail of different model locations.

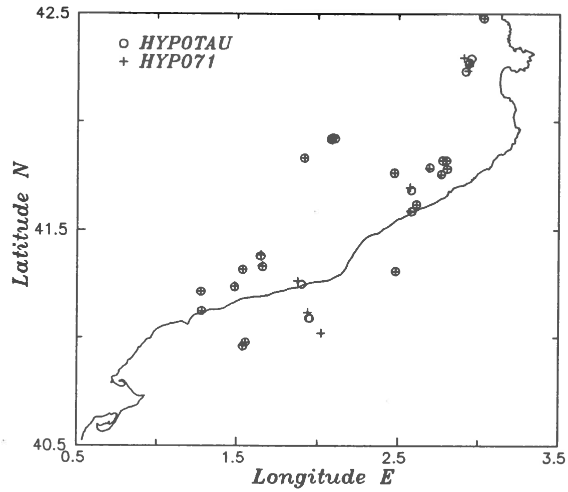

Figure 3: Comparation of HYPOTAU and HYPO71 earthquake location.

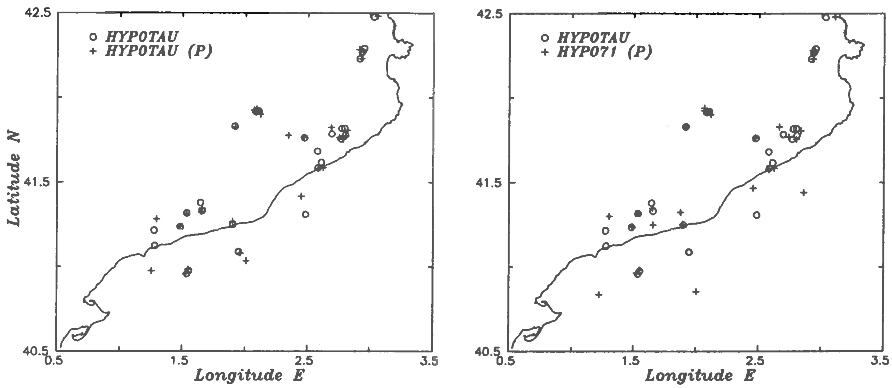

Figure 4: Comparation of HYPOTAU and HYPO71 stability. When only P waves are used, HYPOTAU shows better stability.

ANALYSIS OF MACROSEISMIC AND INSTRUMENTAL DATA FOR THE STUDY OF THE 19 NOVEMBER 1923 EARTHQUAKE IN THE ARAN VALLEY (CENTRAL PYRENEES)

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INTRODUCTION

A project to study 20th century earthquakes in the Northeast of the Iberian Peninsula through retrieving of macroseismic and early instrumental data is being undertaken in the Geological Service of Catalonia. Sánchez Contador et al. (1989) outlined the main aims of this project.

The earthquake of 19 November 1923 in the Aran Valley is one of the most intense (Io=VIII) occurred in the Pyrenees within the present century. There were considerable damage in the epicentral region which at that time was quite depopulated but now is an important touristic area. The earthquake was felt in an extensive zone in the NE of the Iberian Peninsula and the SW of France. The study of this earthquake is of special interest for the evaluation of the seismic hazard in these areas. In this paper preliminary results from the macroseismic and instrumental study of this earthquake are presented.

MACROSEISMIC DATA

An exhaustive revision of the original macroseismic questionnaires that were collected by the Fabra Observatory in Barcelona, together with other complementary information such as letters, newspaper notes and contemporary scientific papers allowed us to re-identify and re-evaluate point intensities (Figure 1). It can be seen that there is a lack of data in the western part of the Spanish region as most of the mentioned questionnaires refer to places in Catalonia (Eastern area). For the French side point intensities from the BRGM-CEA-EDF (SIRENE) (1991) data base have been used. This gives a total of 736 data points, 520 of them having intensity assigned. Some former errors on geographical names and locations have been corrected.

Collected data show relatively large values of intensity quite far from the epicenter (I=V, that is a decrease of only 3 degrees with respect to the maximum intensity, at about 160 Km from the epicenter). Also a large dispersion on the intensity values is present in the overall felt area, being observed different intensities on places at very close distances. This effect is seen either in the Spanish and French regions. Dispersion on intensity values makes difficult to draw isoseismal lines.

In the epicentral area, there are 3 sites with intensity VIII (MSK), the maximum intensity observed. Some damages to buildings, in particular to old Romanesque churches were reported. The center of this concentrated damage area determine the macroseismic epicenter (42°40' N , 0°42' E). It can be seen in Figure 1 that, although the earthquake was felt at distances larger than 300 km from the epicenter, the intensity values decay in the near field is quite abrupt, indicating a very shallow hypocenter. The decrease of intensity with epicentral distance r has been studied taking into account all the point intensities instead of isoseismal lines. Figure 2 shows these data points (squares) on a diagram I_o-I vs. epicentral distance. Sponheuer (1960) attenuation law has been considered:

$$I_o - I = 3\log\left(\frac{\sqrt{r^2+h^2}}{h}\right)^b + 3\alpha\log e\left(\sqrt{r^2+h^2} - h\right),$$

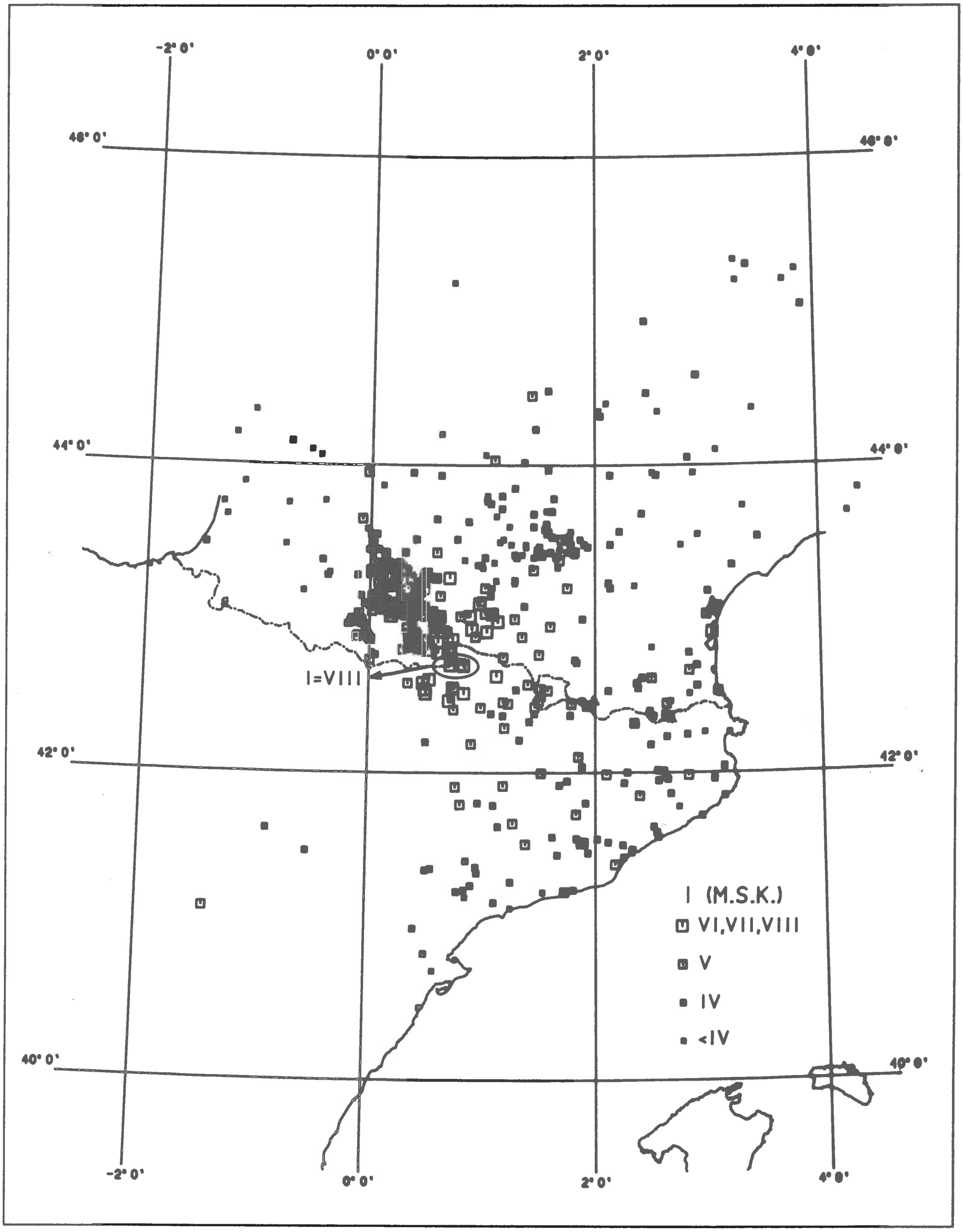

Fig. 1. Geographical distribution of felt intensities. In the epicentral region a circle delimits the area with I=VIII.

where I_o means epicentral intensity, I intensity at a place sited at epicentral distance r, h focal depth, b a geometrical spreading parameter and α the anelastic attenuation coefficient.

The fit of this attenuation law to our data points has been carried out using Levenberg-Marquardt inversion procedure (Marquardt, 1963). The best fits are obtained when b=1 (body waves), values of the attenuation α lower than 10^{-3} km^{-1} and a focal depth of about 5 km.

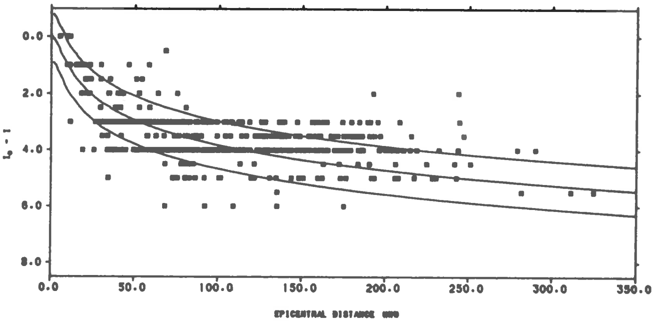

Fig. 2. Io-I vs. epicentral distance. The three solid lines show the fit to Sponheuer attenuation law (± standard deviation).

INSTRUMENTAL RECORDS

The earthquake was recorded at several European observatories. In order to estimate the local magnitude and the seismic moment of the earthquake, records from the nearest stations, FABRA and EBRE, located at 185 and 205 km respectively from the epicenter, and from PARIS observatory, located at about 700 km, have been collected, photographically enlarged, digitized and pre-processed for pen curvature, skew and baseline corrections.

Table 1 gives the instrument constants obtained from the calibration tests performed a few days before or after recording the earthquake. Damping factors of the East component of FABRA and EBRE were too low for obtaining the true ground motion through the transfer function of the instrument.

RECORD	MAGNIFICATION	NAT. PERIOD (s)	DAMPING
FABRA N	68	9.3	0.36
FABRA E	55	6.9	0.03
EBRE E	63	7.8	0.01
PARIS N	134	7.5	0.39
PARIS E	133	9.2	0.43

Table 1. Calibration constants of the instruments.

Therefore, to estimate local magnitude M_L only the N component record of FABRA has been used. Simulated Wood-Anderson seismogram has been obtained through convolution and deconvolution in the frequency domain. Figure 3 shows the digitized seismogram and the corresponding Wood-Anderson record from which a value of M_L=5.6 is obtained.

The seismic moment has been calculated from the S-wave Fourier displacement spectra of the two horizontal components from PARIS, using Brune (1970, 1971) model, obtaining a value of 1.1×10^{24} dyn×cm. Using the relationship between seismic moment, M_o, and local magnitude, M_L obtained by Bolt and Herraiz (1983):

$$\log M_o = 17.92 + 1.1\, M_L,$$

a magnitude of 5.6 is calculated. There is a very good agreement between this estimate of M_L from the spectra of PARIS record and that obtained with the direct computation from FABRA record.

The obtained M_L value agrees also with magnitude M_S obtained directly from amplitude readings of the PARIS records.

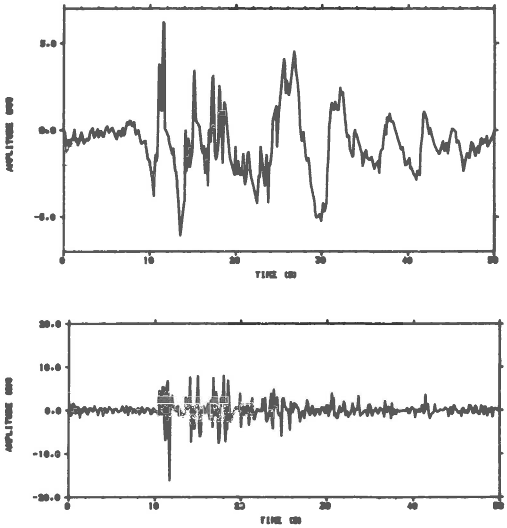

Fig. 3. FABRA, N-component digitized seismogram and Wood-Anderson simulated record.

Finally, our estimates of magnitude from the processed seismograms agree very well with those that can be derived from macroseismic data using the relation obtained by Karnik (1969).

CONCLUSIONS

This paper describes some preliminary results of an ongoing project to compile and review original macroseismic questionnaires and to collect and process early seismograms for XX century earthquakes in Catalonia. Intensities on Spanish sites for the 19 November 1923 earthquake in the Aran Valley have been revised and linked with information on the French territory. From these data a very low anelastic attenuation coefficient ($\alpha \leq 10^{-3}$ km^{-1}) and a focal depth of 5 km are obtained. Instrumental records have been used to compute different estimations of local magnitude and seismic moment. Values of M_L=5.6 and M_0=1.1×10^{24} dyn×cm are obtained.

ACKNOWLEDGMENTS

We want to express our gratitude to the Bureau de Recherches Géologique Minières (BRGM), Commissariat de l'Energie Atomique (CEA) and Electricité de France (EDF) for supplying macroseismic data from the SIRENE file and to the observatories that provide us with instrumental records.

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SEISMOLOGICAL DATA ACQUISITION: NEW TRENDS, OLD NEEDS

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INTRODUCTION

In recent years, advances in digital technology have had a significant impact in seismological data acquisition. Most important contributions were made in the developement of seismic sensors by broadening the bandwidth and the dynamic range. Similar technological progress is achieved in handling the signal, once it is transformed into the digital form. Seismologist have shown great interest in developing various on-line signal processing tools such as event detection, phase identification and data compression algorithms. Which is less known in seismological community is what lies in between the sensor and the digital signal processing unit which is a microprocessor. This intermediate part of the system includes mainly analog electronic circuitry, namely the amplification stage, the Sample/Hold device and the A/D converter. It is often assumed that this part of the acquisition system is taken good care by electronic engineers and the performance margins largely exceeds the limits required by seismological instruments. However this is not necessarily true, especially when working with the state of art sensor technology. In the following an outline is given for what new technologies are available to solve old problems associated with the seismological data acquisition. Various noise sources and their relevance in the context of seismology are discussed. The noise performance of each analog section is treated briefly in order to increase the awareness of simple data users as well as in-house hardware system developers.

ANALOG AMPLIFICATION

The analog signal amplification is the first treatment a signal receives after it comes out from the transducer. It is the task of the operational amplifier (OpAmp) to raise the sensor output to an appropriate level for further filtering and A/D conversion. It is expected that minimum level of noise and distortion are introduced at this stage where the signal is most vulnerable due to its very low level. Performance is influenced essentially by three factors: the choice of a particular OpAmp, the stability of the supply line and the circuit layout. Only the choice of the OmAmp can be studied in a general way.

This step is rather crucial particularly when using high resolution A/D converters (24-bit). As an illustrative example, the supply range of an OmAmp being in general 20V and if an amplification factor of 1000 is used, to be able to use significantly an A/D converter of 24-bit, one must be able to reduce the noise to nanovolt level. One can easily evaluate the difficulties involved in designing this front end. Recently very comprehensive reports related to this problem have appeared in the literature (Riedesel et al,1990, Rodgers,1992, Rodgers,1992), therefore it will not be treated in detail in this paper. It will only be mentioned that there is no point in trying to reduce the OmAmp noise to a level lower than the Low Noise Model (LNM) and the seismometer generated Johnson noise. Figures for each of two types of noise sources can be found in the cited references. Briefly two main types of intrinsic noise are generated in an OmAmp: Johnson noise and the Voltage/Current noise. The first one is spectrally flat and can only be reduced by using lower input resistances. The Voltage/Current noise is of 1/f type, hence brings severe limitations at low frequencies. One can reduce it choosing the appropriate OpAmp or using chopper stabilized ones which have excellent low frequencies characteristics. Finally one must avoid using switch mode power supplies which make life easier for producing negative power supply, but introduce considerable noise.

SAMPLE/HOLD DEVICE

A sample/hold (S/H) device is the essential part of any successive approximation or subranging flash type converters. It is however obsolete for the new generation of oversampling converters. However, since many in house acquisition system developers still use the conventional approach, limitations due to S/H devices are still very much of concern. The essential function of a S/H is to hold the signal at a constant level while the converter is doing its job. A converter cannot handle a signal which changes by more than 1/2 LSB during the conversion time. Hence the S/H device must ideally freeze its output to its input level while the conversion is in progress. This simple looking task is a very challenging linear electronic circuit design. The basic components are: a switch, a capacitor and an output amplifier. Two main types of error are introduced when using a realistic S/H device: time delays introduced by transients and inaccurate measurements due to various leakage problems.

Time delays cause an unpredictable time shift between the exact moment where the A/D conversion is intended to take place and the time it actually occurs. This undesired perturbation in the sampling frequency is random and would certainly disturb the spectral characteristics of the signal. However, these timing errors are mostly effective at high frequencies and therefore are not extremely serious for seismological signals in general.

On the other hand problems associated with leakage in S/H devices are more critical for low frequencies. Three main error types are noted in this context: the feedtrough, the droop and the pedestal. The feedtrough is the transmission of the input voltage to the output while the device is in HOLD mode. This is due to the imperfectness of the sampling switch which behaves like a capacitance. Any change at the input signal will cause the S/H output to fluctuate when it is supposed to remain constant. In actual devices, this is equivalent to noise of the order of 100 dB, hence acceptable only up to 16-bit A/D conversion. The second disturbing phenomena is the droop. The droop is the change in output voltage due to the inevitable discharge of the holding capacitor. The discharge paths are leakage through amplifier, trough the switch and the capacitor itself. The droop is of the order of 0.1 v/sec for a general purpose device. Using the fact that the largest fluctuation allowed for S/H output during a sampling is 1/2 LSB, this device can be used with a maximum frequency of 350 Hz at a resolution of 24-bit. Furthermore the droop is very much dependent upon the ambient temperature (doubling for every 10^0C temperature increase). Finally the pedestal is the unwanted offset due to interaction between the S/H output which is supposed to stay constant and the digital S/H command line. In other words, this is due to stray capacitance between signal and logical lines. Care must be taken in designing the layout in order to minimize this effect. Often it is assumed linear and its effect can easily be removed. For small Hold capacitor, the pedestal is nonlinear and can create harmonic distortion.

A/D CONVERTERS

In recent years there was a considerable effort in increasing the resolution properties of A/D converters. While 16-bit converters were seemingly the ultimate limit few years ago, 25-bit converters are already in the market. There exist two main trends in the manufacturing of high resolution A/D converters: those designed for the highest possible accuracy in the dc sense and those designed for on-line signal processing applications with good ac specs. The first types are targeted for precise measuring systems, while the second is for speech and audio processing.

The conventional successive approximation approach is mostly used for the first type of application. Converters in the 12-18 bit range which are off-the-shelf available in the market are generally of successive approximation type. It has been studied in the previous section that these converters require a sample/hold device which largely limits the accuracy. It is not unusual to have converters providing no missing code performance up to 16 bit while the internal non-linearity may be only of the order of 14 bits ie.~0.003% of full scale range (Swager,1989). It is not obvious at the moment in what way any acquired seismological data is effected by these inherent non-linearities and temperature dependences. Nevertheless successive approximation converters have been most popular in the past and still are probably for most of the in house system developement. More innovative techniques, such as multiple ramp method or voltage/frequency conversion, are also introduced in this context. The main objective in these design is to achieve good linearity (<0.001%) and good temperature coefficient (<0.5ppm/^{0}C) which is actually very tricky to obtain. Resolutions up to 25-bit are obtained trough highly complex techniques. However, these types of converters are often intended for very special applications such as weight measuring instruments, etc. Although accuracy and temperature characteristics are excellent, they are of slow speed and often not easily available on the market.

For the second type of application, where signal processing is of primary concern rather than precise measurement, an entirely different approach is applied which is called the oversampling or the delta-sigma converter. This is a new technique with rapidly increasing popularity. The approach this time consists of using a 1-bit converter with an extremely high sampling rate. The continuous bit stream is then transformed into a word based binary stream. The advantage lies in building a higher portion of the device (>90%) on entirely digital basis. This is one of the main reasons which make this device of very low cost. State of art in seismological data acquisition system which use up to 24-bit resolution are based on these oversampling converters. Although they cannot compete with successive approximation counterpart for absolute accuracy, they are ideal for high-speed mid-range accuracy. One drawback is when digitizing very close to dc which is not unfamiliar in seismology. This state allows the converter to generate repetitive outputs. If the period is low enough, generated noise may fall into the converter's bandwidth corrupting the output signal. Manufacturers use different techniques to suppress this unwanted behavior. The final disadvantage is that since it is a signal tracking device it is not suitable for multiplexing, therefore a separate converter needs to be used for every independent input channel.

CONCLUSIONS

An outline of new technologies available for analog circuitry in seismological data acquisition is given. It is emphasized that most components which are often assumed to have perfect characteristics, are not so when pushed to the limits of their characteristics. Upgrading from conventional resolution (12-bit) level to high resolution converters (eg. 24-bit) is not an easy task. Particularly, in-house hardware developers for seismology who design their system with only a moderate noise immunity (such as PC based systems), have to be cautious in going to resolutions above 20-bit.

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Chances and Limits in Automated Seismogram Processing

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Introduction

The last decades have seen a dramatic increase in data quality of seismic network starting from analog paper recording at single sites to the high-frequency arrays like NORESS or GERESS with dozends of stations. In parallel to this development, the amount of raw data grew from MB to GB per observatory and day and the number of events, hided in noise but still detectable rose from 10 to 100 a day. It is obvious that nowadays we reached the limits of human processing capabilities. The increase in storage capacity developed by an unexpectedly innovative computer industry will still allow us to save all our recordings. But without automated processing, it would only be a feeble excuse to our inability to utilize the advances of seismological measurement techniques any more.

What we expect from an automated observatory is the detection, location and identification of all the routine seismic events down to the detection threshold with human-like performance. This would yield an automated bulletin and the seismologist could focus his rare time to the inspection of questionable exceptions, new phenomena and the final interpretation of condensed event statistics like the annual epicenter maps. Our only problem in realizing this dream is that we demand automatization most uregntly for the large number of repitive small events which are hard to capture because of their decreased signal to noise ratio.

Detection on Single Traces

The history of automated seismogram processing started with the STA/LTA detector based on the theoretical approach of Freiberger. It just performs detection on single traces which is lightyears away from our needs of an automated bulletin. Nonetheless it was the first time that seismology entered the new field of unmaned data interpretation and was confronted with criteria like false alarms, missed events or the receiver operating characterists (ROC). While everybody knew that human processing is by no means without error, they were usually taken as god-given. Automated processing is different as it demands a conscious discussion and decision about performance versus security trade-offs. Like in a burning glass, all the discussions in the seismological community about reasoning or lack of it behind automatization have focused on this first step of single-trace detectors. This is in sharp contrast to their actual simplicity, similarity and predictable performance. As explained for the STA/LTA detector in Fig. 1, even with the additional step of postprocessing it demands just 8 parameters for optimum tuning. But experience has shown that by not understanding their impact we can choose this parameter set so to miss any event or to produce numerous false alarms. The principle processing units - filter, powermeter, statistics and decision logic - are found in all other variants like the WALSH-detector, the SRO-detector or the approaches from Stewart or Allen (Joswig, 1990). Their inherent paradigma - detecting any deviation from the permanent noise process as event - is also the cause of their common and principle weakness: They *must* trigger false alarms for every sonic bang, traffic noise, explosion and spiky interferences.

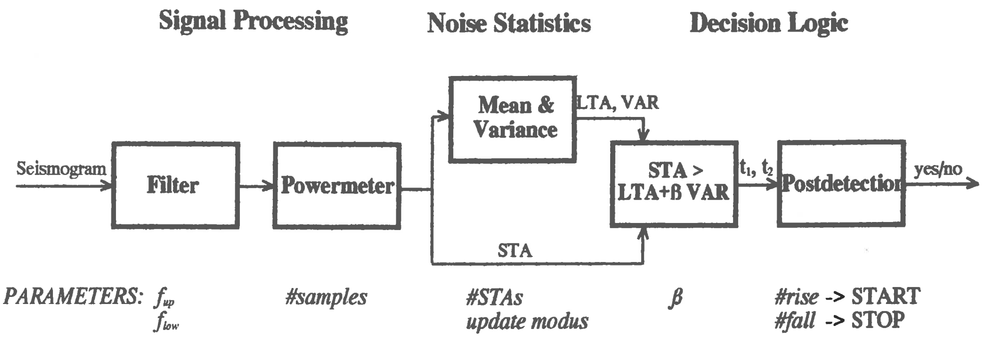

Fig. 1 Basic Elements of STA/LTA-like Detectors

Coincidence Reasoning

The inherent weakness of single-trace detectors can only be tolerated if additional processing steps compensate for it. The most simple and earliest approach is voting, i.e., the test on coincidence in detection timing on different sites. This is quite a powerful criterion since noise sources are local and seismic wave propagation is spatial. Only explosions and casual correlation of noise bursts will pass this test unjustified. If still there is demand for more sophisticated reasoning like by expert sytem rules, then it comes from the needs of postprocessing. The price for robustness in the detection process is fuzzyness, so its results are unsufficient for the final event analysis, e.g., the hypocenter location. Here we need a more accurate picking of onset times. This step is very much enhanced if it is knowledge-guided, e.g., we can start on the actual subset of best stations to proceed to the weaker ones and also test all results on plausibility with standard travel time tables. A good example for this appraoch is given by Chiaruttini et al. (1989). Once the rule base is adopted to the specific situation, we can expect 80 - 90% success rate for the automated bulletin.

Parameter Extraction for Seismic Arrays

The situation for automated seismogram processing gets completely different in case of seismic arrays. Now we can utilize signal coherence to enhance the signal to noise ratio on the resulting array beam. This alternative processing scheme is slightly superior to voting (Wirth et al., 1976). An even more significant benefit results from the spatial sampling of the wavefield. By means of the f-k analysis we can distinguish P- and S-phase onsets by significantly different slownesses and can resolve ambigious phase groupings by the test on common azimuths per event. The most advanced example for this path of automated seismogram processing is RONAPP and its implementation to IMS at NORSAR (Mykkeltveit & Bungum, 1984; Bache et al., 1990).

Monitoring by Sparse Layouts

The situation changes once again if we can't base our evaluation on many seismic stations. Either we just face a small event that is not recorded by more than the adjacent stations or the always restricting limits on funding have resulted in a tripartite array site (see Fig. 2). It is important to note that this simple change in quantity converts to a distinct quality for the approaches of automated seismogram processing (Joswig, 1992a). In case of a sparse network, no redundancy is left to identify and correct for wrong phase picking at single stations; also we need the S-onset times which are very hard to determine in local seismicity. In a sparse array the beam is often worse than the best single station, so coherence processing can not help. However, the voting scheme will yield many false alarms and postprocessing can't be based on f-k analysis due to the unsufficient spatial sampling.

As a result of these restrictions, parameter extraction is much more significant for sparse layouts than for dense onces. To achieve satisfactory performance demands more intelligent approaches than just STA/LTA detection or any of its relatives. The fundamental alternative is pattern recognition on single traces either based on syntactic or pictorial descriptions of the desired and rejectable waveforms. On the other hand, the restricted number of stations also limits the variety of situations that must be handled by any subsequent rule-based system. So the trade-off between dense and sparse layouts is the simple parameter extraction and complex expert system versus sophisticated parameter recognition and rudimentary reasoning. Other criteria are in common like a multi-layer approach starting by fuzzy recognition and proceeding to hypothesis-guided postprocessing for highest possible resolution as well as the expectable rate of success from 80 - 90% of the routine situations (Joswig 1992b,c; Klumpen & Joswig, 1992; Schulte-Theis & Joswig, 1992).

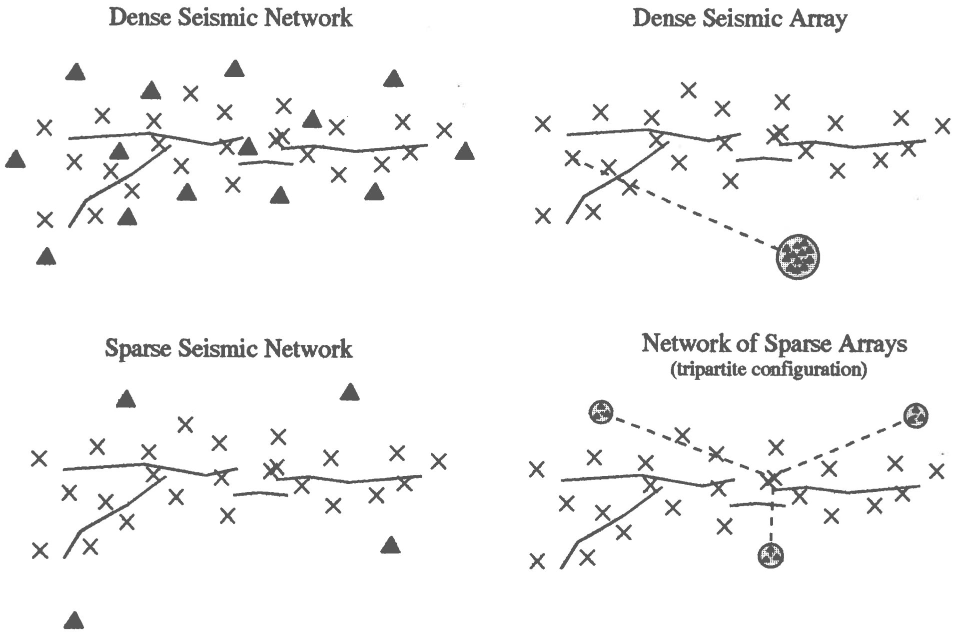

Fig. 2 Seismic Monitoring by Different Geographical Layouts

'Bottom-up' in Seismology

All approaches discussed so far - either expert systems or pattern recognition on syntax or images - fall into the class of 'top-down' methods in Artificial Intelligence. This phrase is intended to characterize the explicit coding of knowledge in consciously performed descriptions. The principle alternative is 'bottom-up', i.e., constructing a self-learning algorithm that adapts itself independently to the environment. In consequence we can't expect to reason, justify or modify on its internal knowledge representation. Either the system works or we must continue in its 'training phase'.

Promissing candidates of this paradigma are artificial neural networks for any kind of recognition tasks and simulated annealing or genetic algorithms for a universal inversion scheme. However, the severe weakness of all these approaches at date is their slow convergence in the training cycles which prevents their application to the complexity of real world data. To achieve some managable parameter dimensions, e.g. for phase picking, demands a very carefully chosen preprocessing by decimation filters, determination of spectral weights or other intendedly defined signal processing. In general, these prefilters dominate the problem solving so much that ANN as the pattern recognition unit is just the top of cream on the cage of 'top-down' processing. This comment does by no means disqualify 'bottom-up' as a very promissing tool for handling confused situations once the self-organization is accelerated enough.

Conclusions

The task of automated seismogram processing shows - besides its necessity to be solved for any future progress in seismic monitoring - considerable complexity that excludes the application of simple solutions. As our problem proceeds from detection to suppression of false alarm, then location and finally identification, so does the diversification of algorithms. Starting with the optimal filter we separate into pattern recognition versus expert systems, then we subdivide into knowledge representation by image or syntax, frames, scripts or fuzzy logic. The more details our coded knowledge includes the less portable the system gets.

The only firm ground at date are preliminary recommendations: Field stations should just rely on STA/LTA-like detectors as long as we can't forsee the desired signals. Many station observatories - either array or network hub - will focus on expert systems based on a more primitive parameter extraction while sparse layouts must rely on sophisticated single-trace algorithms complemented by simple rules.

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AUTOMATIC EVENT DETECTION OF TRIGGERS IN DIGITAL AUTONOMOUS SEISMIC STATIONS.

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Aim of this work has been to investigate systems of signals recognition for autonomous digital stations in order to adapt the trigger algorithm to different kinds of seismic data.

To do this we have used data obtained with three components digital acquisition units, both with centralized and local recordings.

In both cases, stations consisted of a DCF receiver and a MARS88 acquisition system: in the case of centralized station, linked with the I.G.G. network, it was the MODEM model, in the case of local recordings the F.D. type. This one has been used in the six digital stations installed twice, the first time between May and July 1991, the second in the period November1991-May 1992, in the area represented in figure. The same area had been used for the installation of a network consisting of 6 analogic stations that had operated from February to April 1988. This can be seen in the same figure.

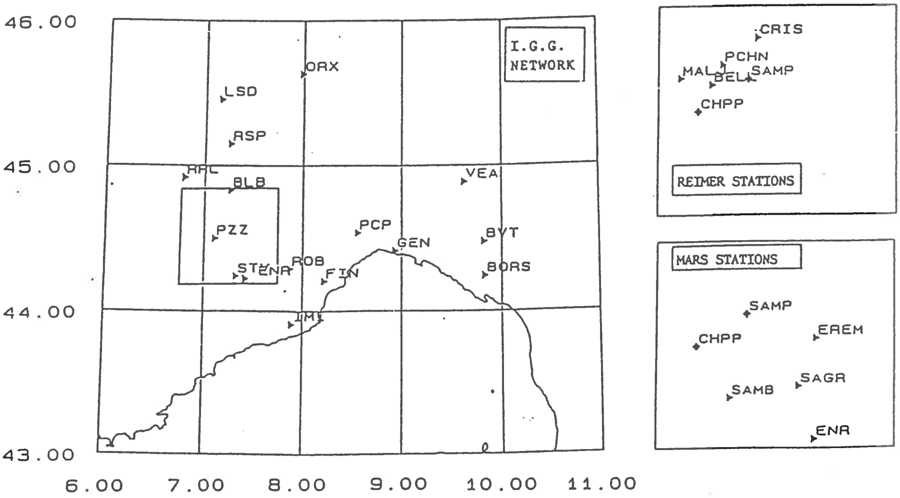


Figure 1: The I.G.G. network and the temporary network installed in 1988 and in 1991-1992

The choice of the region was made because, even if it does not reach the maximum energetic level of the Mediterranean area, it is affected by a quite diffuse and frequent activity, especially concentrated in the Southern sector of the Western Alps, roughly coincident with the Alpine part of the Cuneo province. Another important reason for the choice of the area is the fact that it is almost covered with stations belonging to the I.G.G. network, that has been used as a comparison for the performance of the digital stations.

For our Department this installation has represented the first attempt of use of digital acquisition units with single trigger: this fact needed a particular care in the choice of the sites, paying great attention to the value of noise level. This need is clearly in contrast with the general phylosophy that leads a temporary network use that is to do a quick, easy and cheap installation. To get a good compromise , every site was choosen takin' into account the easiness of access, the existence of some kind of building for instrument recover and of course the noise level. This is very important because his knowledge helps the operator to choose the right value of LEVEL in the trigger algorithm, that is : STA > (RATIO*LTA)+LEVEL

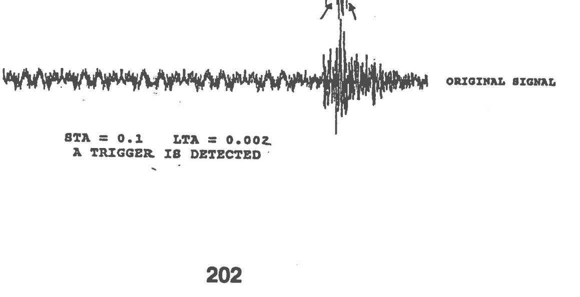
In the first period of recordings, our aim has been generally to get the largest possible number of noises and signals to have a great amount of data to work with.

The second and most important part of the work has consisted in creating a program able to reproduce the acquisition process.

The program works with a Butterworth two poles two zeros filter.

It's aim is to simulate the performance of the acquisition unit and to permit to the operator to change the variables that leads the trigger algorithm and to see what happens because of the change. The problem of the value of STA, consisting in the fact that the program treats only single recording, that is without takin' into account previous value that in the real acquisition are coming from the last recorded trigger, has been resolved creating a pre_event data by multyplying a certain number of pre-event champions. Many tests have been conducted varying RATIO, LEVEL, STA, LTA, the values of filters . We have established that the trigger algorithm is very sensible to the changing of the values of STA, as can be seen in Figure 2 and Figure 3. Another important dependence is that from the bandwidth of signals : the choice of a certain low and high pass filter permits to distinguish between signals and noises.

Different kinds of families of noises have been recognized between the recordings. Making their spectra, we have realized the filter we must use to avoid the recording of a certain kind of noise. So, for example, if the goal is to get only local earthquakes, lookin' at the spectra of the noises that represents the possible false triggers it's clear that the band 5Hz-10Hz is free from noises and is adapt to our goal, being not infact the most energetic one in a signal comin' from a local earthquake (Figure 4). Figures 5 and 6 reports the results obtained using such a filter.



STA = 0.1 LTA = 0.002
A TRIGGER IS DETECTED

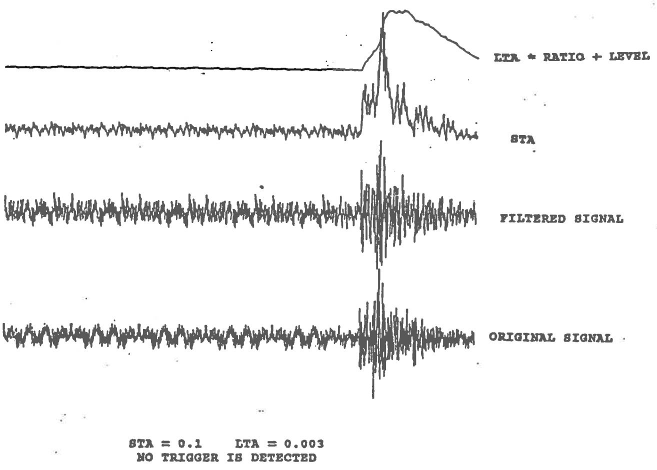


Figure 2 and 3: the trigger algorithm is very sensible to the changing of STA and LTA. The trigger is here marked with a dot-dot line.

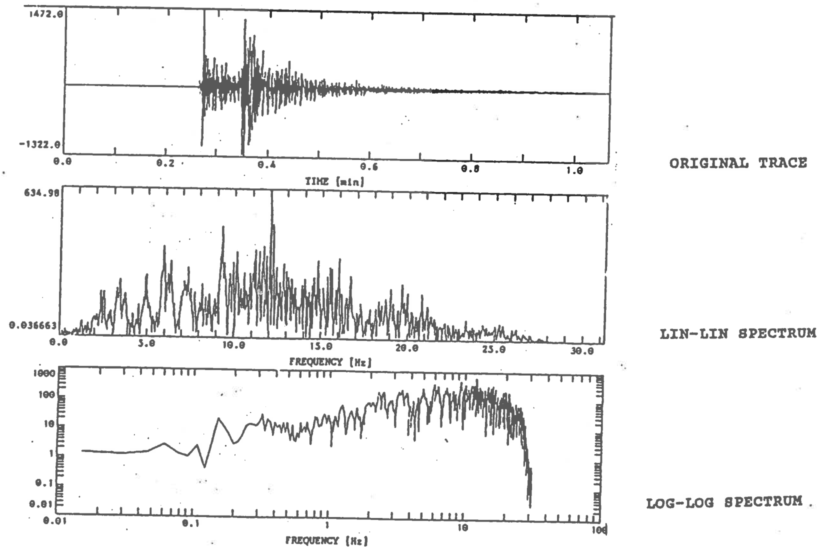


Figure 4 : Spectra of a signal of a local earthquake. The band 5Hz-10Hz it's not the most energetic one.

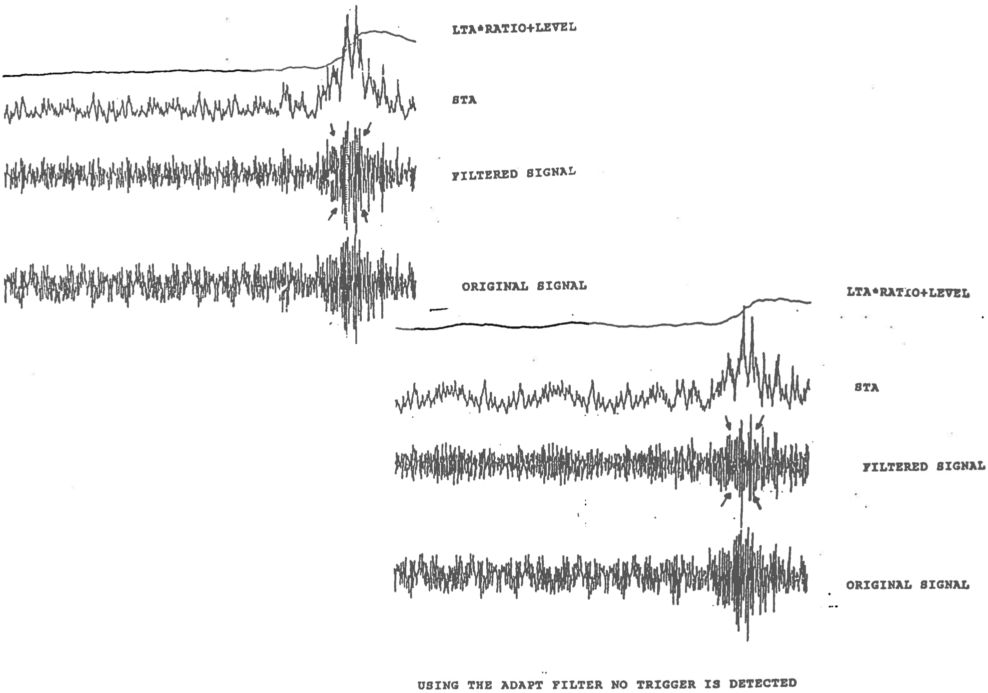


Figure 5 and 6: Different behaviour of the algorithm using two different filters. If the filtering band is 5Hz-10Hz, no trigger is detected

In cases in which noises are represented by a thin spectral band, the best thing would be to use a Bandstop filter or, in the case of a single frequency, a Notch filter. Obviously their use would be applied in the phase of recognition of signals but not in the phase of acquisition as, infact, happens for the implemented filter.

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POLARIZATION DETECTOR

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INTRODUCTION

Most detectors that are in routine use today are single vertical channel detectors, which monitor changes in incoming energy level. Three-component data give more information to be used in detection process. Because of this several detectors using three-component data have been developed in recent years, (Pisarenko *et al.* 1987), (Magotra *et al.* 1987) and (Ruud and Husebye 1992) to mention a few. The drawback in using three-component data is often highly increased computing time. For example continuous polarization analysis is time consuming when matrix computations are employed. Our aim has been to develop a reliable and fast detector, which will take into account both incoming energy and changes in polarization state.

POLARIZATION FILTER

Before detecting we are optionally using a simple predictive polarization filtering to enhance P-wave onsets. We use "predictive coherence" as defined by (Roberts *et al.* 1989) to compute measure for amount of linear polarization for each sample. Predicted coherence is computed from 3 second window after each sample. If amount of linear polarization rises above certain threshold sample is multiplied with a factor which is describing amount of linear polarization ahead of it. Effects of this kind of filtering on a local event are shown in Figure 1. The P-phases are clearly amplified.

POLARIZATION DETECTOR ALGORITHM

The actual detector is trying to find rapid changes in polarization state. We don't try to find out type of polarization only the changes. We can do this without solving eigenvalues of covariance matrix simply by taking cross-powers of vertical and horizontal components. We compute cross-power of vertical channel with both horizontal channels separately. The cross-powers are computed from 5 second long sliding windows. Step between two consecutive windows is always one sample. In this way we get two new time series with the same sampling rate as original seismogram. Then we find largest difference from current point to 0.2 seconds backwards. These differences from both cross-powers are added together. The result is kind of a derivative curve with dynamically changing time step. To get the final decision curve (Fig. 2.) we divide each sample of the derivative curve with long term average of 5 minutes. Values that exceed certain threshold in this curve cause a detection.

AUTOMATIC ONSET PICKING WITH POLARIZATION METHOD

For automatic phase picking we use two different methods. The polarization method is more powerful for finding first P- and first S-phase. Before phase picking we filter the data with narrow BP filter. The filter is chosen according to the center frequency of the detection. Data is also filtered with polarization filter. The method is similar to that we used for detecting. The only difference is that instead of dividing derivative curve with 5 minute LTA, we divide each sample with 3 sec average, which is taken ahead of it. This is done because after phase arrival polarization state is usually steady. This is seen as low level in derivative curve which shows changes in polarization. So peaks in the decision curve, which lie at onset of a phase, are amplified by the division.

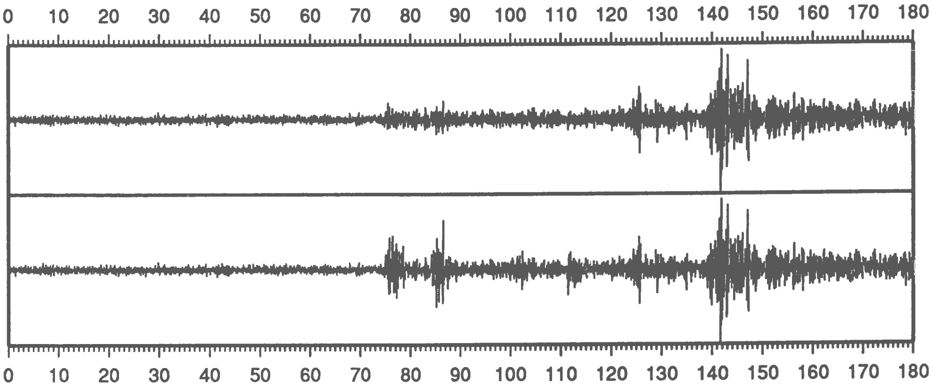

Fig. 1. Example of polarization filtering. In the upper picture highpass filtered (2.0Hz) vertical channel and in the lower one same trace after polarization filtering. The event is a quarry blast from northeastern Estonia, ML=2.6. Distance to station VAF is 480km.

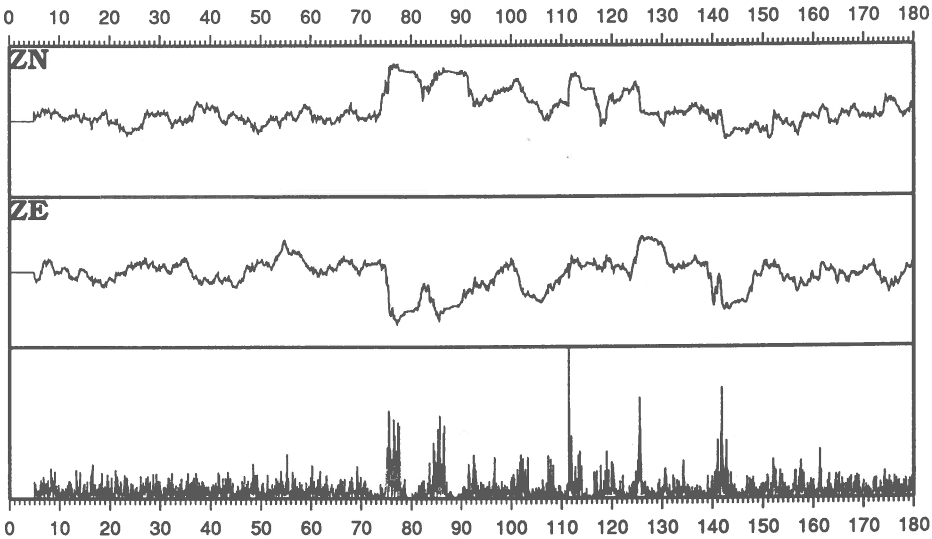

Fig. 2. Cross powers of vertical and horizontal channels and the decision curve of the detector.

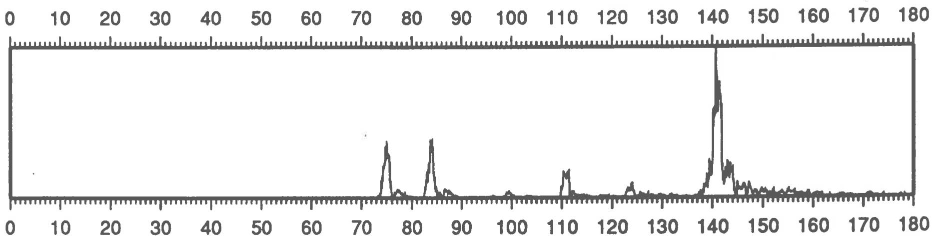

Fig. 3. F-test curve of the same event as in previous pictures. Some crustal phases give clear peaks in the F-test curve.

AUTOMATIC ONSET PICKING WITH F-TEST METHOD

The F-test method is more suitable for picking later phases. F-test is simply a ratio of variances of two populations. We compute F-test from two consecutive sliding windows from data. The window length is very short, usually under 0.6 seconds depending on the sampling rate. The resulting curve has peaks on phase onsets where, nature of data changes. This method is sensitive to changes both in amplitude and frequency. With 3-component data we first sum up amplitudes of each channel and take F-test from resulting curve but, method can be used with any single channel.

We use F-test curve also to recognizing local events. We compare average of F-test curve of certain time window to the peak values of the curve. This gives us simple method to automatically separate possible false alarms and detections caused by spikes from local event detection list.

TEST RESULTS

Teleseismic events

The detector computes azimuth, slowness, vertical to horizontal amplitude ratio, dominating frequency and predicted coherence. We use vertical to horizontal ratio, predicted coherence and slowness to suppress the amount of detections of each station before making final detection list. Detections with unfavourable values in all 3 parameters are excluded. To gain speed we did not use polarization filtering with teleseismic events. The advantage of polarization filtering is also here lower since, small teleseismic events don't have long enough steady polarization state.

Polarization detector was tested against SRO detector, which we are currently using with our network. It is peak-to-through detector developed by Murdock and Hutt (1983) for Seismological Research Observatories. With this detector in our routine system we are currently using 6 filtering bands. To detect small teleseismic events means setting detection thresholds so low that, amount of false alarms would be very large. So we use voting system with two sets of three stations and take to the final detection list only those events that have been detected on each of the three stations.

The test was made so that we used 2 three-component stations and took to the final detection list events that were detected on both stations. The data was filtered with one BP filter 0.9Hz-3.5Hz. Parameter settings for SRO detector were the same as in our routine system. This way we got from 67 to 227 events per day. Polarization detector was tuned so that amount of detections per day was about the same.

During a test period of 9 days our routine system found 97 teleseismic events. The test configuration of SRO detector found 58 of the events. This was done using only one filtering channel compared to 6 filters in the routine system. Polarization detector found 81 of the events found by our routine system. The daily detection rate was rather high but it can be reduced by using more stations. With SRO detector using 3 stations instead of 2 lowers the detection rate about 75 percent.

Local and regional events

We tested polarization detector to local events using only one station. We chose three-component substation of FINESA miniarray. We tried to tune the detector so that we could get most of the events in FINESA automatic location list with as few misalarms as possible. The data was prefiltered this time with 2Hz HP filter and then with polarization filter. Polarization filtering makes it possible to detect first P-phase instead of later phases in case of many small events.

On test period of 9 days the detector made 486 detections, that is only 54 detections per day. On the same period FINESA had located 105 local events. Of these events polarization detector found 76. 50 detections were made from first P-phase, 21 from Sg and 5 from other phases. We went trough all detections of 2 days and found out that, false alarm rate was very small, below 6 percent. Most of the other detections that were not in FINESA location list were small local events and teleseismic events.

COMPUTING SPEED

In Table 1. there are some examples of computing speed. The actual detector is very fast. It takes only 15 seconds to run 1h of 20hz data on SUN sparc IPC. About 4 seconds of this time went to reading data from discloop. The band pass filtering increases run time only a little to 22 seconds. Polarization filtering increases the run time more significantly to 56 seconds, even though polarization filtering is done without matrix computations. With higher sampling rates run times grow up fast. As can be seen from tests done with 100Hz data.

Test run	20Hz data	100Hz data
Polarization detector	0:15	1:20
Polarization detector + BP filter	0:22	1:51
Polarization detector + BP filter + polarization filter	0:56	12:40

Table 1. Examples of computing speed on SUN SPARC IPC with sampling rates 20Hz and 100Hz. Band-pass filters used were 3rd order Butterworth filters.

CONCLUSIONS

The polarization detector uses also incoming energy for detection, but it gets addition to detection capability from polarization effects. Hence it is more effective than STA/LTA, SRO or other detectors, which concentrate only on monitoring variations in energy level. Still the detector is faster than those detectors, which examine polarization by solving several parameters describing wave field. Especially detectors using matrix computation to solve eigenvalue systems are inefficient unlike our detector when considering computing times.

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SEISMIC MONITORING OF A MONUMENTAL AREA IN ROME

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GENERAL DESCRIPTION

ENEA (Italian National Agency for New Technology, Energy and the Environment) has a long time experience in the field of seismic monitoring with the aim to find safe places to realize nuclear power plants. In fact ENEA from many years designs, realizes, manages local or radio-transmitted (radio-relays or satellite) seismic and accelerometric networks. On the base of this background by mean of an agreement with the National Trust for the archaeological monuments was designed an accelerometric network with the scope to validate a new research methodology to prevent vibration damaging.
Since September 1988 ENEA began the realization of an advanced digital accelerometric data acquisition network to control the natural (seismic) and man-made vibrations induced on some historical monuments in Rome.
The aim of the acquisition of seismic related data in a monumental area in Rome is to improve the knowledge on structural rensponses during vibration to develop and to increase the quality of methods and of technologies to maintain and to restore the structural state of the monuments. Because many structural damaging caused from earthquakes and man-made vibration (particularly traffic) have been found on the historical monuments of Rome.

NETWORK DESCRIPTION

Nowday the network is composed of four accelerometric data acquisition systems (CODISMA) developed in a collaboration ENEA-Contraves Italiana. Each CODISMA is located close to a particular historical monument as follows:

1) Traian column, N°2 CODISMA (one at the base and one at the top);
2) Palatino hill (Domus Augustea), N°1 CODISMA;
3) Caracalla Thermals (Mitreo), N°1 CODISMA.

As soon as possible will be realized other two acquisition site one at Coliseum (N°1 CODISMA)(4) and another at Antonina Column (N°2 CODISMA one at the base and one at the top).
During the set-up of the network particular attention has been paid to the realization of adapt sensor interface with the target do not compromise the stability and the aesthetic of the monuments.

DATA ACQUISITION AND INSTRUMENTATION

The acquisition system is the accelometer CODISMA designed and developed properly to be a stand alone acquisitor capable working in severe environmental conditions with high reliability.
It works with a pre-selected threshold, as low as the local environmental vibration.
To have a good quality of the recorded data and a long MTBF (Mean Time Between the Failure) of the instruments, all the CODISMA have

been provided of a good electrical earth (<20 ohm) and protected from extra-voltages on primary power supply with a high-voltage decoupler transformer.

MANAGEMENT

The acquisition instrumentation is controlled and verified one time per month. During the control are retrieved possible recorded data and checked all the operative functions and the state of the electronic. All the operations are made with a simple portable personal computer IBM compatible. The recorded data are retrieved with the PC and stored directly on the hard-disk or floppy-disk.

DATA ANALISYS

A first elaboration of the data may be performed directly in field with the provided software, that permits to display the time history and the frequency response. After the data are to be examined with dedicated software to obtain informations about the velocity and the displacement. These information are necessaries to study the dinamic behavior of the structures under investigations.
The acquired knowledges permit to increase the capability to restructure the damaged monuments and to made stronger the structure to resist better to the vibrational actions
The elaborated data are inserted in a dedicated digital bank, and the recordings and the elaborations are made availables to the users on the international scientific computers network.

FUTURE IMPLEMENTATION ON THE NETWORK

Today the network is a local network, is our intention to realize a centralized management performed via radio. In fact the Codismas have a RS232C standard interfaces that permit the connection to a radio-modem. In this way will be possible to connect the acquisition center of Casaccia directly with the equipments in the hart of Rome via a short (about 10 Km) UHF radio-relay link, performing a polling interrogation (automatical at prefixed hour, after an event, on request) of the singles data acquisition sites.
Moreover will be replaced the actual sensors with others more sensitives and will be implemented more sophisticated software based on spectral analysis of the acquired signals with the aim to acquire lower level vibrations.

CODISMA

Defense from the eartquakes begins from the their knowledge. The study and the propagation mechanism of seismic waves in earth layers and the analysis of dinamic behavior of the structures are the means to reach this target.
Today protection and prevention criterias foresee monitoring networks tailored to characterize seismic areas, integrated with specific analysises on particularly interesting structures as monuments, bridges, dams.
From the precision and reliability of collected data depend the validity of the antiseismic models and the capability to find effectives solutions against earthquakes effects.
For a valid monitoring it needs to have availables instrumentation of high quality adapt to acquire data with high reliability and precision also in severe environmental conditions. CODISMA (COntraves DIgital Strong Motion Accelerometer) developed from a collaboration ENEA-Contraves Italiana is an accelerometric data acquisition system

born to satisfy the above requirements. CODISMA has been designed and developed on military standards, to work in critical environmental conditions (temperature, shocks, humidity, power supply spikes and electromagnetic interferences).
CODISMA is adapt to be employed in accelerometric monitoring networks either in free-field or on structures.
CODISMA has been employed from many governative and civil companies for seismic and structures monitoring (ENEA has also an accelerometric network composed of 7 CODISMA in Val Nerina, a zone of Umbria Region).

TECHNICAL FEATURES

<u>Accelerometric head</u>	
Accelerometric sensors	
-number of sensors	three (one per axis) PCB 393C
-full scale	+-2.5 g
-resolution	<0.036 mg r.m.s
-cross-axis sensitivity	<3%
-linearity	<1% F.S
-frequency response	0.025-800 Hz
<u>Control electronic</u>	
Antialias filtering	
-type	7 poles Butterworth
-cut-off frequency	88 Hz (3 dB)
-available gains	0/10/20 dB (Selectable)
A/D Converter	
-bit	16
-delay among channels	0.25 ms
-sample rate	25/50/100/200/300/400 SPS software selectable
-default value	200 SPS
-clock stability	10^{-6}
Controller	
-CPU	80C86 microprocessor
-technology	CMOS
-bit	16
-CPU clock	4.9152 MHz
-work memory	16 kbytes
-EPROM	64 kbytes
Event trigger	
-internal	threshold on one axis (ONE) or on all axies (ALL)
-external	from dedicated connector
-threshold level	1-255 mg-(1 mg steps)
Data elaboration	
-pre-event memory	1-10 s-(1 s steps)
-post-event memory	1-10 s-(1 s steps)
-data compression	dinamic reduction with total restoring of former data
-efficiency	depending from spectral response of recorded signal typical values 0.4-0.7
Serial line	
-type	RS 232C-7200 baud
Memory	

-card size	224 Kbytes or 896 Kbytes
-memory card	up to 4
<u>Power supply</u>	
-external	220 V/50 Hz
-battery	12 V or solar celles
-internal	Pb battery 12 V 12.5 Ah
-consumption	160 ma
-memory card 224 Kb	TO6/43 litium
-memory card 896 Kb	DS3GT NiCd
Autonomy	
-with internal battery	>3 days
<u>Phisycal features</u>	
-weight	25 Kg
-dimensions	0.49x0.29x0.34 m

AUTOMATIC DETECTION OF P AND S WAVE ONSETS FOR LOCAL EVENTS

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INTRODUCTION

The method to be reported is suitable for automatic identification and onset detection of body waves of local seismic events recorded at a single three-component seismological station. In view of the importance of S-P differences for epicentre localization, special emphasis is put on the exact times of both P and S wave onsets. The method is tested on both synthetic and real data and routinely used to analysing selected events of the 1985/86 Western Bohemia earthquake swarm. The best results are obtained with autoregressive fitting statistical algorithms, suplemented with an analysis of polarization properties from the covariance matrix.

DATA CHARACTERISTICS

A characteristic feature of three-component recordings of local seismic events is the appearance of Pg and Sg waves in the noise background.

For the P waves the background is given by permanent ambient seismic noise. In the case of the S wave, P_{coda} noise is superimposed to the former predominantly uncorrelated and unpolarized noise. The signal generated P_{coda} is correlated and has complex polarization properties.

Within the pass-band of the used short-period seismometers, the predominant frequencies of the P and S waves generally do not significantly differ either from each other or from those of the seismic noise.

As frequently observed in teleseismic events, the P and S waves do not exhibit a pure linear polarization. For the P wave, the main axis of the polarization elipsoid can be determined. After a correction for the influence of the free surface, the orientation of this axis corresponds to the azimuth. The S wave is mostly polarized perpendicularly to the direction of propagation with the azimuth consistent with the P wave azimuth. In anisotropic structures this situation is more complicated. For the effective transverse isotropy with a horizontal axis of symmetry, the projection of the direction of polarization of the split S1 and S2 waves in the horizontal plane is independent on the direction of propagation.

The amplitudes and especially polarization properties of P and S waves thus differ from those of the noise. The prerequisite of a successful automatic detection is a basic estimate of the amplitude, spectral and polarization properties of both the noise and the wave to be detected. This estimate is achieved by an interactive analysis of typical sets of seismograms.

DETECTION METHOD

The developed method is based on successive cascade application of separate functions for rough detection, identification, estimation of polarization characteristics, and exact detection. The rough and exact detections consist in the approximation of stochastic multidimensional noise and signal time series by autoregressive processes. The rough detection is realised by applying of simple STA/LTA criterion and noise prewhitening. The exact approach is based on the detection of abrupt changes by means of the maximum likelihood function (Pisarenko et al., 1987).

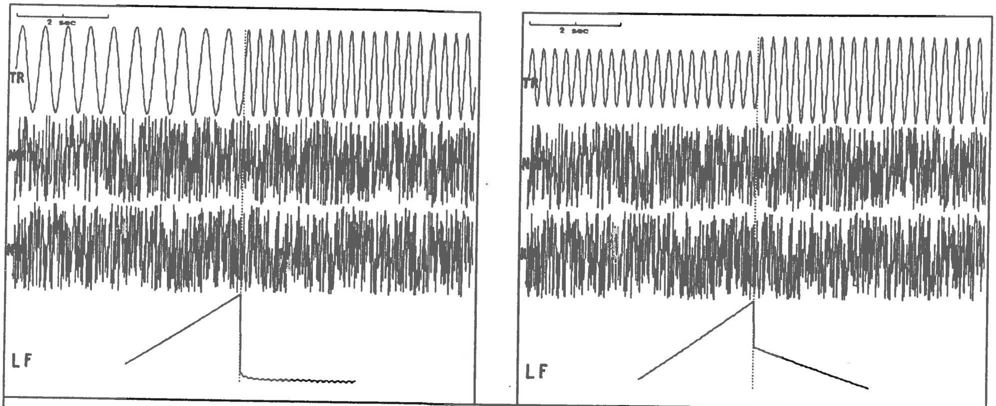
The algorithm works in a selected window partitioned step by step into two parts. To ensure a proper autoregressive approximation, the partitions must be sufficiently long and homogeneous, and at the same time the window must be sufficiently short to contain only one body wave group.

Automatic detection and estimation of the polarization characteristics of seismic waves are procedures necessary for

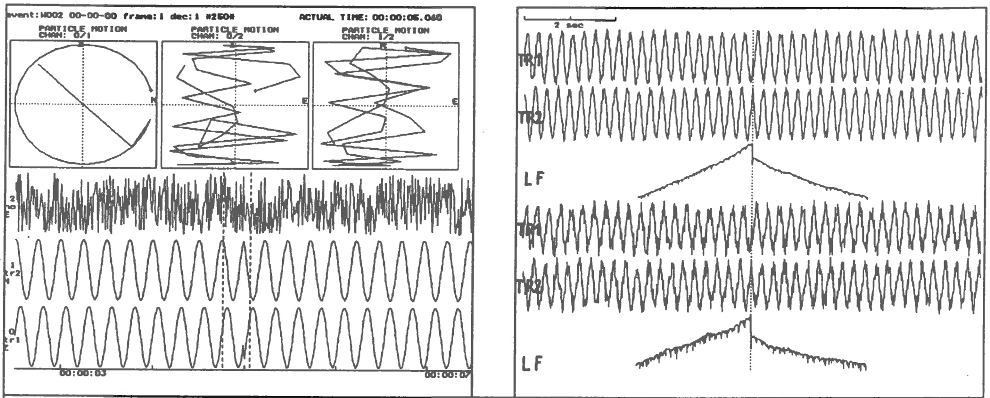
- the discrimination of P and S waves,
- an optimal rotation of signal to improve the resolution of the onset detection,
- simple tests of the detection reliability.

These procedures are based on the covariance matrix analysis by the methods of eigenvalues and maximum likelihood testing of conformity with the theoretical model matrix (Roberts and Christofferson, 1990).

The automatic detection method was tested by means of synthetic data representing small abrupt changes of amplitude, frequency and polarization of noisy three-component time series. The tests confirm a high detection accuracy of the method as you can see in the figures.



Tests of amplitude and frequency difference detection capability. Maximum of likelihood function (LF) indicates instant of change. Two (NOI) traces represent random noise.



Test of polarization difference detection capability. Circular polarization is changed to linear polarization. Two traces (TR1, TR2) show signals, the third trace (NOI) represents random noise. The detection method was applied to the signal with superimposed white noise of 25% (upper traces) and 50% (lower traces) maximum signal amplitude. Maximum of LF indicates instant of change.

DATA PROCESSING

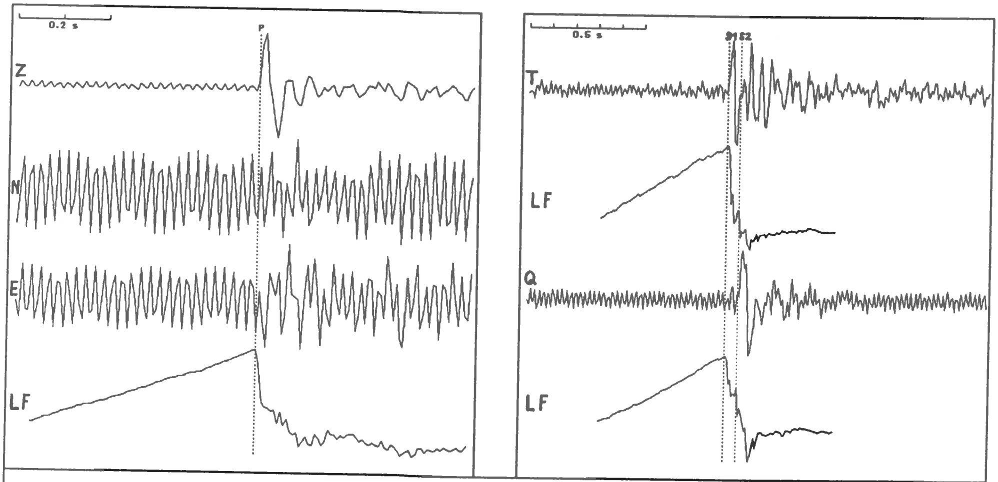
Selected events of the 1985/6 Western Bohemia earthquake swarm were used to testing the performance of the method. The set of used seismograms from station VAC is characterised by the presence of S wave splitting caused by transverse isotropy with the horizontal axis of symmetry. The horizontal projection of the S1 waves corresponds to the angle of 31 deg. and the direction of polarization of the S2 wave in the horizontal plane is nearly perpendicular to that of S1. The P wave is polarized approximately linearly in the direction of its propagation. For the majority of events of the set the P_{coda} level is rather low and the P and S1 waves can be clearly identified.

A comparison with interactively performed reference measurements yielded an agreement of 90% (+/- 1 sample = 0.007s) and 85% in the detection of P waves and S1 waves, respectively. S2 waves were successfully detected in about 60% of treated cases. The figures on the next page document the case of the successful detection of the P S1 and S2 waves.

RESULTS

Routine processing of a large amount of seismograms confirms a high detection quality, but on the other hand, it reveals the essential limitations of the method. The results of automatic detection of P and S wave onsets in three-component seismograms of local events are quite comparable with those obtained by detection with the aid of the interactive analysis.

Such ideal results, however, are only obtained in the cases in which no other significant phases are present. The most severe limitation in practical application of the presented detection method is the impossibility of a reliable automatic estimation of the accuracy of the automatically determined onset times.



Exact detection of onsets P, S1 and S2. The traces are unnormalized and T, Q are rotated to the directions of polarization. Maxima of likelihood functions indicate onsets.

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LOCAL SEISMIC NETWORKS WITH DIGITAL DATA PROCESSING

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INTRODUCTION

Mining Institute of Czechoslovak Academy of Sciences in Ostrava concentrate geophysical research upon the study of physical processes in rock massif and design of special geophysical apparatusses. In geophysics we work especially in the area of induced seismicity. During the past period we constructed the local seismic network in Czechoslovak part of the Upper Silesia Basin (Ostrava-Karviná Coalfield, OKB) for mines with methane and coal dust explosion risk (Lazy Colliery) and the regional seismic network in the southern part of OKB. Digital signal processing is used for both networks.

LOCAL SEISMIC NETWORK IN LAZY COLLIERY (OKB)

Seismic network consists of five underground and three surface three-component seismic stations and a PC computer based analysis system. It has been installed in the area 2 × 1.5 km in the Lazy Colliery.

The seismic network is destined for providing information on the fracturing in the rock mass, particularly with a view to the safety of men in the respective mine working. For this purpose, information on the position of the focus of an event and on its approximate energy must be provided simply and quickly. There must be also the possibility of using the data from this network in the whole seismological monitoring system of the OKB.

The network represents also an experimental base which ensures the generation of sufficient quantities of good quality seismic data for basic research.

Block diagram of this seismic network is on the Fig. 1. There are seismometers S5S and telemetric transmitters PCM3-T/Tx placed at the surface stations (Z6, Z7, Z9). Digital signals from surface stations are transmitted via telephone line to telemetric receivers PCM3-T/Rx in the central recording station. At the underground stations (Z0, Z1, Z2, Z3, Z4) there are seismometers SM3-JB, which are connected by cable to intrinsically safe inputs of apparatuses PCM3-JB.

The modular system of used digital seismic apparatuses PCM3 ensure digitalization of analog signal from seismometers in the frequency band 0.01 - 30 Hz in dynamic range of 90 dB and its digital signal transmission and recording. The sampling frequency is 100 Hz.

The recording system ensures the acquisition of data from individual PCM3 apparatuses, the formatting of these data and their recording on a standard computer magnetic tape together with the time code. The recording system decides on the triggering of the record. The system makes it possible to record events of any duration (the only limitation is the capacity of hard disc or the magnetic tape).

The analysis system is implemented on PC AT computer. Software working under a program system WINDOWS. It was developed in Mining Institute of CSAS and consists of the following programs:

- analysis of wave patterns
- location of seismic phenomena focal points
- spectral analysis
- analysis of focal mechanism

Software for converting the data format was developed in the Mining Institute of CSAS so that data could be processed also by seismic analysis system SAP 58000 of Lennartz electronic company. The data could be converted to ESTF format.

The seismic network has been put into operation in November 1989. Continuous registration of seismic phenomena has been functioning since the beginning of 1990.

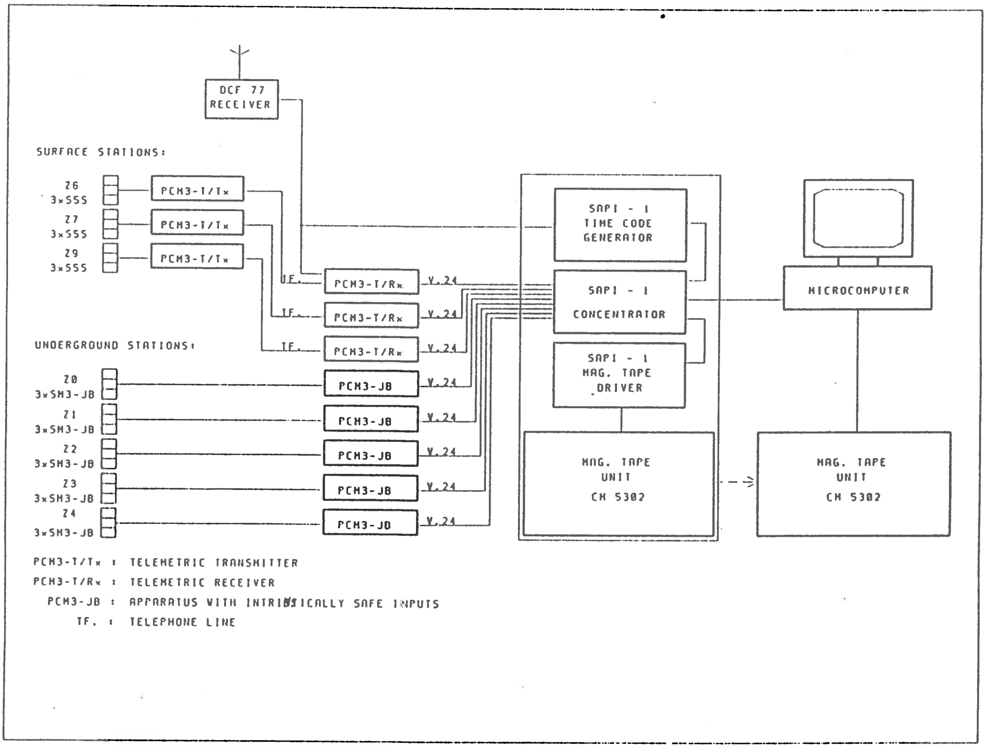

Fig. 1
Block diagram of local seismic network in Lazy Colliery (OKB)

REGIONAL SEISMIC NETWORK IN SOUTHERN PART OF THE OKB

The seismic network has been built up for purposes of seismic research in the area in which a coal production is expected to start in future. The network consists of 5 three-component seismic stations (SS1 - SS5) with radio telemetric data transmission into a central recording station (CRS). Because SS are located in the mountain terrain of the Beskydy Mountains it is not possible to realize a direct radio telemetric connection with CRS in all cases. Therefore at the highest point of the Beskydy Mountains on Lysá Hora a relay station (RS) was erected, through which signals from all seismic stations are transmitted to the central recording station - Fig. 2.

At the seismic stations (SS) oriented seismometers WDS-202 are installed in boreholes in the depth of 30 m. Analog seismic signals are amplified, digitalized and transmitted by radio channel to relay station. Seismic signal amplifiers contain 6-pole Bessel type anti-aliasing filters with corner frequency of 30 Hz (-3 dB). Three ranges of sensitivity can be selected in the station (4 - 1 - 0,25 µV/LSB). The used digital floating point code (10 bits mantissa, 4 bits exponent) enables the transmission of signals in the dynamic range of 120 dB (MSB/LSB). The sampling frequency is 125 Hz, the sampling shift between channels is 500 µs.

The equipment of relay station (RS) consists of five radio receivers, data concentrator, fast time code generator and radio transmitter. The data concentrator and time code generator are implemented by microcomputers. The fast time code generator is synchronized by received time code DCF 77,5 kHz. It is automatically operated even during interruption of DCF signals reception. The concentrated digital seismic signal with time code is transmitted by Miller code to CRS via radio. The resultant accuracy of allocation of time information to seismic data is always better than +/- 2 sampling intervals.

The central recording station equipment consists of radio receiver, data preprocessing unit (PPU) and recording computer (RC) of PC AT type with magnetic tape unit MTU. In the PPU received data are decoded. An output of analog signals from 5 selected channels is available. From PPU the data are continuously transmitted by DMA channel into recording computer, where they are recorded in a triggered mode on a hard disc. For trigger the STA/LTA algorithm is used and a coincidence of trigger symptoms of individual stations in particular time window. The parameters of triggering algorithm are entered in a dialogue mode or as a data file. From the hard disc the data can be transferred to a floppy disc, magnetic tape or to another analysis system via serial port. Programs of recording computer safeguards also keep of network operation log in which information on seismic stations operation are recorded (i.e. interference of safety circuit, interruption of mains supply), on transmission faults from relay station, on faults of DCF time signal receipt and on recording computer reset.

For data interpretation we use the same analysis system as for local seismic network - see above. The recorded data can be also composed by SAP 58000 analysis system of Lennartz electronic company, or eventually they could be converted to ESTF format.

The seismic network in the southern part of OKB has been put into operation in November 1991. A continuous registration of seismic phenomena has been functioning since the beginning of 1992.

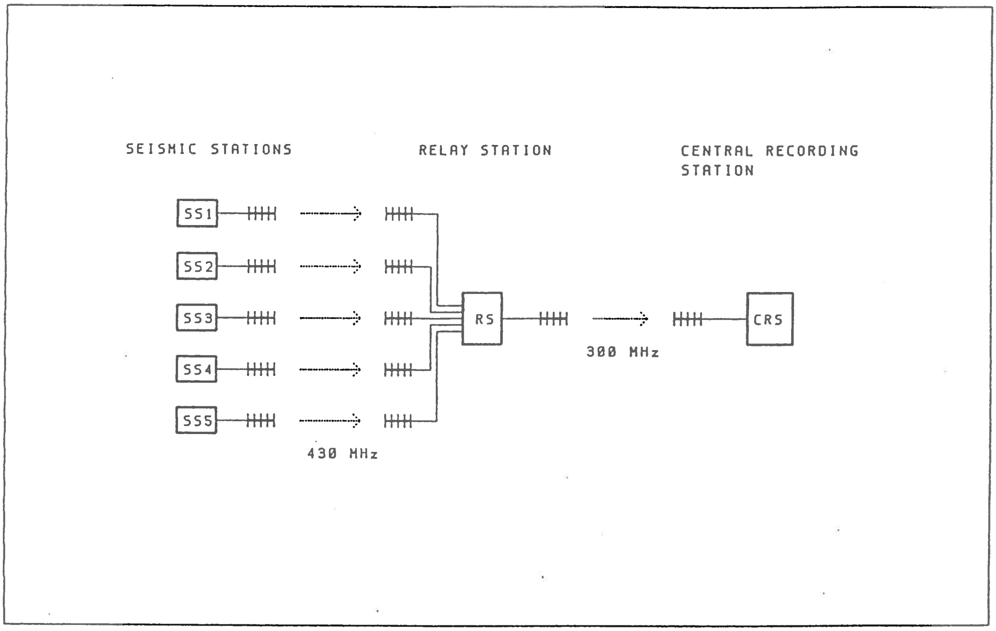

Fig. 2
Block diagram of regional seismic network in the southern part of Ostrava-Karviná Coalfield

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PIEZOELECTRIC SEISMOMETERS: RECORDING POSSIBILITIES AND APPLICATION PROSPECTS

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At present electrodynamic pendulum seismometers are widely put into practice. The period of such seismometer pendulum is usually longer then the maximum period of the recorded vibrations. As a result, the rigidity of elastic suspension is relatively small and the dimensions and mass of pendulum are relatively big.

For strong motion recording are usually used high frequency accelerometers. The piezoelectric sensors are optimal in this application.

Piezoelectric sensors are widely used for a time in vibrometry and acoustic for frequency range of hundreds hertz up to hundreds kilohertz and more. The first piezoelectric seismometer was proposed by B.B.Golitzin in 1915. After that many autors proposed different variants of piezoseismometers. But only after putting into practice of field-effect tranzistors it became possible to make suitable and reliable piezoelectric seismometer(Fremd,1969).

The principle and electrical scheme of piezoelectric seismometer are clear from fig.1.

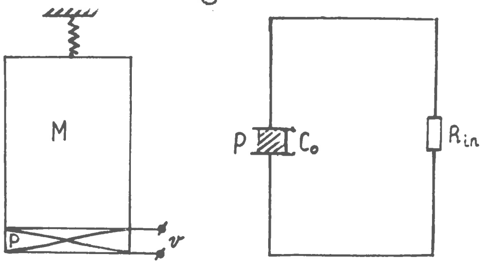

Fig.1. Principle and electric scheme of piezoseismometer

Piezoelements of seismometer are usually also his elastic elements. Dimensions and configuration of piezoelements determine sensor electric sensitivity and seismometer eigen frequency.

Piezoelectric accelerometer has rigid reliable mechanical system with relatively high resonant frequency. Lower frequency boundari of piezoaccelerometer is determined by time constant which depends on electrical capacity of piezoelements and input resistance of amplifier. Really in piezoseismometers this frequency is about several hundredth up to several tenth of hertz. Frequency characteristics of undamped high quality mechanical system of piezoaccelerometer is close to ideal.

On fig.2 is shown the general scheme of three-component piezoaccelerometer with cubic common inert mass. Such accelerometer APT-1M (Fremd,1976) with sensitivity of 2.5 V/g and frequency range of 0.15 to 1000 Hz was designed for strong motion seismology and is in production since 1963.

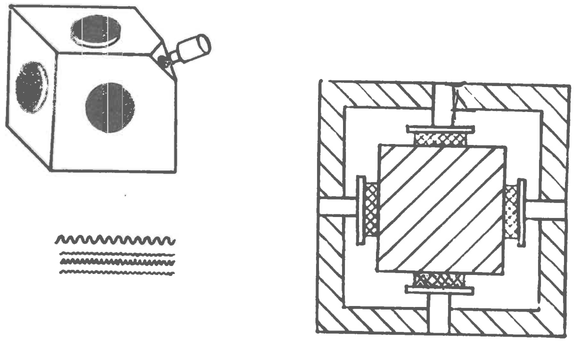

Fig.2. Scheme of three-component piezoaccelerometer APT-1M

The problem of calibration is very significant for seismic instruments. Electromagnetic device for inner calibration of three-component accelerometer with common inert mass is shown on fig.2. Electromagnet is fixed in instrument so that the force that pulls the inert mass is directed along the cube big diagonal and is the same for each component.

In 1983 we proposed and developed the princip of symmetric three-component piezoseismometers with common inert mass (Fremd, 1990). This princip is clear from fig.3.

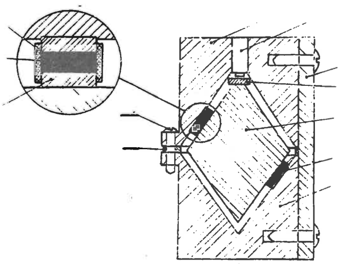

Fig.3. The scheme of symmetrical three-component piezoseismometer

Now in production is three-component piezoaccelerometer TAF with follow main parameters:

Output sensitivity 5 V/g;
Frequency range 0,2-1000 Hz;
Dynamic range 120 dB;
Maximal recording acceleration 2 g;
Transverse sensitivity 4 %;
Operating temperature -20 - +40 ^{o}C;
Dimensions: diameter 85 mm, hight 115 mm;
Mass 2 kg.

Fig.4 shows in terms of vizualised record the curves of maximum accesable sensitivities of various channels with piezoseismometers (Fremd, 1984).

We assume that this sensitivity and the time-constant corresponding to the necessary lover boundary frequency are obtained dy suitable commutation of piezoelements of seismometer sensor and by the selection of its other principal parameters. Also, fig.4 shows the schematic sensitivity curves of standard traditional seismographs SK (1),SKD (2) and SKM-3 (3). So the channels with piezoseismometers can covered the possibilities of traditional seismic channels.

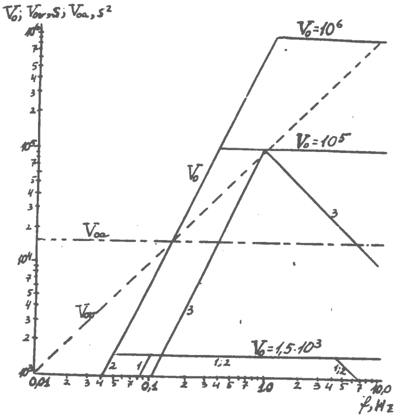

Fig.4. The sensitivity curves of seismic channels with piezoseismometers

In 1992 we elaborate three-component high-sensitive piezoelectric velocimeter TPV. The main parameters of this instrument are follows: resonant frequency about 500 Hz, freqency range 0.1-100 Hz, resolution 15 nm on 1 Hz frequency, dynamic range about 100 dB, diameter of housing 150 mm, weight about 12 kg.

We plan using of high-sensitive piezoseismometers with fixed frequency characteristics, which are optimal for high-sensitive digital seismic channels. Such channels will be especially convenient for digital nets and arrays of seismometers with common central computer. The prototipe of such computerized seismometric system functions at three Yugoslavian seismic stations since the beginning of 1991. This system works with system of digital acquisition of seismic signal DAS (Fremd et al.,1992). Except digital recording DAS provides on-line and off-line data processing.

More then 300 earthquakes of magnitude from 1.8 to 5.7 was recorded with such systems during 2 years. An example of record is shown on fig.5.

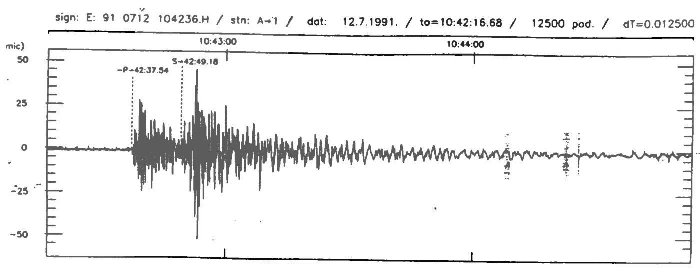

Fig.5. Record of the Timishoara earthquake 12.07.91 at Belgrade station. Accelerometer TAF and DAS-system

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SEISBASE
A PC PROGRAM FOR SEMI-AUTOMATIC ANALYSIS OF LOCAL NETWORK DATA

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1. INTRODUCTION

The PC-software SeisBase was designed for the purpose of processing of triggered recordings from local seismic networks, especially from those compiled from autonomous seismic stations with no trigger information exchange. In such a case no event association is made in the data acquisition period and each station provides self-triggered data with a lot of false triggers. This specific property defined the first requirement for the developed program: to enable a quick overview and deletion of the waveform data.

A local network usually collects up to thousands of seismic events during one year, considering quarry blasts, too. When processing such amount of data a database-like approach may be useful. It allows to get some information without accessing the real waveform data (Berger et al, 1984) which need not be on-line on the disk. This approach enables a quick access to a certain event and/or a group of events, too.

For the purpose of comfortable and quick interpretation all the useful routine work is supposed to be included in one program. In order to simplify the user's work all the useful data should be accessible at once (for instance the event location, depicted in the map together with the waveform data and other information). In the case of special analysis the interpretation program should be able to preprocess a selected set of data automately and provide a well-arranged output (for instance the phase picks, spectra of the wave groups).

The last desired property of the program was simple, semi-automatic manipulation. For routine work no special options are needed and the number of menu operations should be minimized. In most cases the program may use the default settings which can be changed by the operator only when necessary. Furthermore the operator should do only that work (press those keys) which cannot be made automately. All other operations (keystroke sequencies) may be included in programmable macro-instructions.

2. PROGRAM FEATURES

In this section the required properties as they were implemented in the last revision of the SeisBase software are described. The program is structured in two basic levels.

The database level manages all available data (waveforms, phase picks, hypocentral and topographical data) and allows to link them together in order to draw epicentral maps, compile bulletins and so on. Furthermore it enables to select events matching desired characteristics, to display seismograms or histograms, to locate events, to delete selected events or to backup them to another disk and to do other useful work.

The analysis level is intended for basic seismogram interpretation. It provides tools for the transformation of records (filtration, rotation, numerical operations, polarization analysis), phase picking and localization.
Some of the interpretation steps and program facilities will be described in the following.

2.1 Data format

The waveform data format supported is the binary and ASCII format created by the stations MARS-88 manufactured by Lennartz electronic and the format of the older station PCM-5800 of the same manufacturer. The station parameters, phase picks, hypocenter parameters and other information is stored in separate ASCII files.

2.2 Program control

The SeisBase program is fully menu-driven and is controlled by means of keystrokes. No mouse control is available. Keystroke sequencies mey be shortened using macro-instructions.

2.3 Event selection (database level)

When starting work, the user can set a mask which will be used for event selection. The event characteristics available are: station code, first time, last time, type of event (local earthquake, blast, regional event etc.), event name, event identification (name of the source area etc.),number of triggering stations, day in week and day time. From the database all events matching the filter are loaded regardless of the presence of their waveform data on the disk. Then the database program level is run.

2.4 Primary processing (database level)

In the time of data import to disk (floppy-disk dump, tape decoding) a simple database is created. The SeisBase program needs it for data handling and it contains the parameters of each seismic record on each station. These parameters are: start time of the record, it's length in 500-sample blocks and the station code.
During the primary processing three more parameters may be added by the operator: the type of event, it's name and a comment. The event name serves for the association of coinciding triggers. At this interpretation step the user asks for next event and all coinciding records are displayed by the QuickView utility. If the event type was not defined previously, the user is asked to set it. Depending on the entered letter the event is designated or it is marked as a false trigger. Marked triggers may be deleted inclusive of the database reference, or the corresponding waveform data may be deleted or copied to another disk.

2.5 Macro language

20 keys (F1..F10,Ctrl-F1..Ctrl-F10) with different contents depending on the program level enable to write simple programs using key sequencies and a macro special language. This simple language provides basic elements like loops (similar to

repeat..until, finished by counter or a seismogram value), jumps to labels, calling of other macros up to 7 levels and others.

2.6 Phase picking (analysis level)

Up to 7 stations (21 channels) may be loaded to the analysis level and displayed at once on the screen. All manipulations are valid for the active station who's vertical component is displayed in the full loaded length on the top of the screen with the selected time window indicated (see Fig.1). Except of manual phase picking automatic phase picking using polarization analysis similar to that described by Magotra et al.(1987) is implemented in the macro language. The parameters of the phase picking procedure may be set by a modification of the macro program. For P-wave arrivals the method provided approximately 80% of correct and 5% of wrong picks, the rest was not found.

2.6 Seismogram transformations (analysis level)

The active station window may contain up to 9 traces which can be created by the user. For this purpose the menu 'Operations' is available which enables numerical operations with the traces. These are integration, derivation, filtration, goniometric and cyclometric functions, arithmetical and logical (comparing of traces) operations, rotation, polarization and spectral analysis and others. This facility supported by cursor operations (searching typical values of the trace) is a powerfull tool for experiments with detection algorithms.

2.7 Localization (both levels)

Two possibilities are available for determining the source coordinates. Since both the methods use the homogeneous half space they are intended for the first overview only or for discrimination between earthquakes and quarry blasts. Both display the results in the topographical map and can use phase picks and azimuths, too.

The first one, 2-D pattern localization displays the residual function by means of color map and shows the position of the minimum. If there are more minimal points, the user may choose the most probable one.

The 3-D localization uses iterative algorithm and shows both the epicentral position and the depth in the graphical manner.

2.8 Event identification (database level)

When the localization of a couple of events is made, a 2-D or 3-D foci map of marked event smay be displayed. The epicentral position of event under cursor is highlighted and it's seismogram may be displayed in another window (see Fig.1). For the decision about it's origin a report from quarries for corresponding date may be listed at the same time.

2.9 Bulletin compilation (database level)

For the purpose of bulletin compilation or data output for further off-line processing, a list of marked events may be created. The user can choose which items stored in the database system are to be listed (trigger characteristics, arrival times, amplitudes, frequencies, hypocentre coordinates and others).

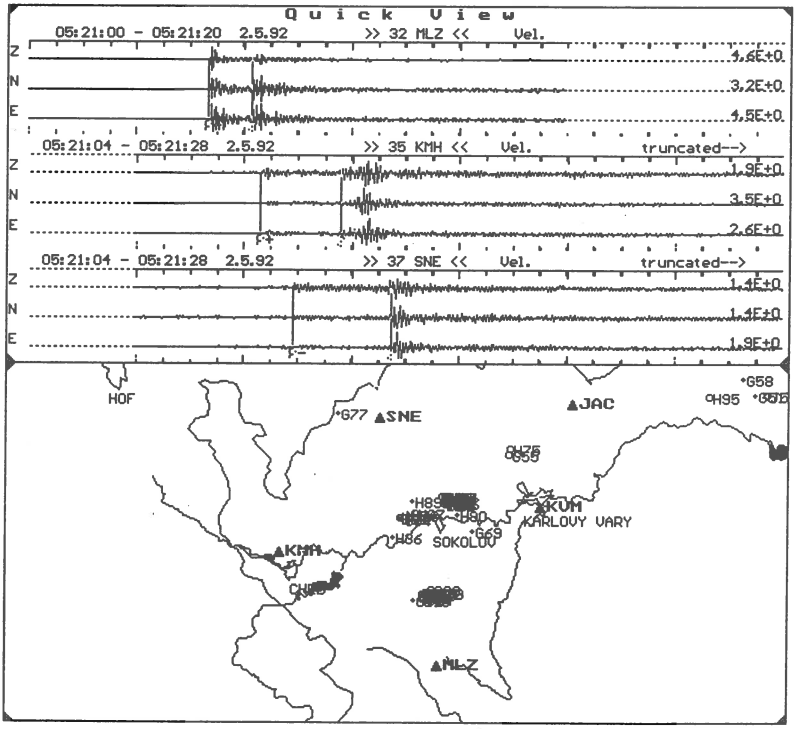

FIG.1. Example of the screen layout when the event is associated. The epicentre map is displayed simultaneously with the seismogram. The epicentre of the displayed event is highlighted (not seen on the screen dump).

3.CONCLUSION

The ideas which lead me to create the SeisBase program and some of it's properties were briefly described in this paper. The software was designed for routine work especially but it provides a lot of possibilities for deeper signal analysis too. It is used for more than one year for processing the data from the West-Bohemian spa network and is intended to process records from a network in the Kladno colliery. It is beeing updated in order to get the best performance security of the data. For this purpose it is supposed to change the self-written database system by some commercial index-accessed database.

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ACTIVITIES OF THE ESC-WG HISTORY OF SEISMOMETRY FIRST RESULTS OF THE CENSUS OF INSTRUMENTS AND DOCUMENTS OF THE EUROPEAN SEISMOLOGICAL TRADITION.

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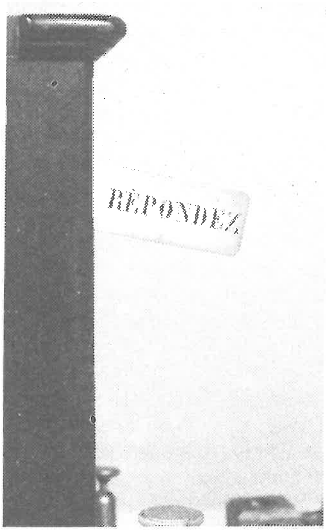
INTRODUCTION



Many times this bell rang when earthquakes occurred in the Seventies of the nineteenth century and any time it asked *repondez* "please answer".
It seems to ask to seismologists to aswer with instruments and theory to the earthquake. And many italian and European seismologist aswered and are still answering.
But now the bell rings to remember us the lossing of the traces of our seismological tradiction. The scientific tradition in Europe has played, especially in the nineteenth century, a fundamental role in the birth and development of seismology.
We are not referring to the tradition of a European scientific community, but to the whole formed by the single individual contributions of scholars from different national scientific traditions.
In fact, although seismology established itself as a science in the last decades of the nineteenth century, it was only at the beginning of the twentieth that an international seismological community began to emerge.
In spite of his young age this scientific community, during his development, progressively eradicated from the historical context and from his tradition.
As a result, an enormous, extraordinary, scientific, historical and cultural heritage is lossing. There are instruments, often selfmade by seismologists, some hundred thausand of seismic recordings, station-handbooks, papers and scientific corrispondance between seismologists.

THE ESC WORKING GROUP HISTORY OF SEISMOMETRY

To reverse this negative trend, in April 1991 the European Seismological Commission set up the new Working Group *History of Seismometry*.
The aim of the WG is to improve the co-operation between seismologist and historians of science and scientific instruments in the retrieval, study and evaluation of the historical heritage of scientific observation of earthquake in Europe.
This research sector has only had up to now disappointingly of modest interest within the seismological framework and is often a mere cultural interest to which a few personal resources are dedicated.
Anybody can consider this a secondary aspect both from the scientific and the cultural point of view. It should be enough to remember the importance of the critical interpretation of historical data had in general but in particular the instrumental ones in the study of big earthquakes of this century.

The history of seismometry cannot be reduced to a mere chronological order of the appearance of seismic instruments; these events should, instead, be linked to the scientific, cultural, economic reasons which caused them, that is, to connect oneself directly to the history of scientific thought within the framework of the science of the Earth.
For this reason it is important to outline the history of sites and persons to understand better that of the instruments.
A correct multidisciplinary contribution between seismologists and historians of science and scientific instrumentation is fundamental to enhance a multidisciplinary approach to the history of seismometry.
Then the WG activities would like to overcome the disciplinary barriers and to find points of comparison between the two disciplines, seismology and the history of sciences.
This project is based in Europe but contributions, suggestions and future developments can involve the whole seismological community.
Very often the interest for these aspects is in contrast with the objective difficulty in tracing the historical data and documents often scattered in different places.
In 1990 the Istituto Nazionale di Geofisica (ING) in collaboration with SGA Storia Geofisica Ambiente (Bologna) started the TROMOS project, a vast research programme on the history of Seismology in Italy from the XVIII to the XIX century (Ferrari 1990, 1991, 1991).

ACTIVITIES AND RESULTS

Starting from the experience of the TROMOS project, at the beginning of 1992 the WG *History of Seismometry* started a census of the historical centres (private and public) of the material preserved in existing centres and of historical seismic instruments.
250 questionaries to seismologists and historians of science and scientific instruments have been sent.
60 of them sent me an answer (about 25%): from Portugal, to Siberia, from Etiopia to Sweden. Also seimologist and historians of science from USA, Japon, Canada etc. are shown interest to the activity of the WG.
In most case (80%) in the old observatory or somewhere, somethings (such as part of instruments, instruments, papers) still exist.
In few cases instruments are still in operation. In general, historical papers are not in special archive well ordered and preserved.
Because of the difference in the kind of papers (fotocopies of old papers, pictures, maps etc.) and in the relative languages, an up-to-date picture of the existing materials it wasn't been possible to trace. For that it will be necessary to integrate the information received with that available bibliographically (e.g. Lee et alii 1988) after the necessary verification.
The analysis of the questionnaire outlined the serious threat of losing a considerable proportion of the historical heritage of European seismology. This could occur mainly where there is not the necessary cultural sensitivity, or in practice where monetary funds, to conserve and re-evaluate instruments, seismograms and historical documents, are lacking.
The results of this census will shortly be made available in a more concise format to interested parties so facilitating future collaboration.
The special recommendations, to highlight high risk situations such as deterioration or loss of instruments, seismograms or historical documents, was given in the special session devoted to the History of Seismology at the XXIII General Assembly of the European Seismological Commission in Prague.

Aknowledgments
Special thanks to Dr. V. Schenk for kindly allowing me to examine the original seismograph designed by Karl Kreil and built during his stay in Prague (1845-51) (Fig1). The instrument is now conserved in the Mining Department of the National Tecnical Museum.
Furthermore, thank you to everybody who has collaborated, in the compilation of the questionnaire and or in any other way assisted the work group.

Anyone interested in the WG's activity, those in the field of seismology and those of history could address all enquires to the autor.

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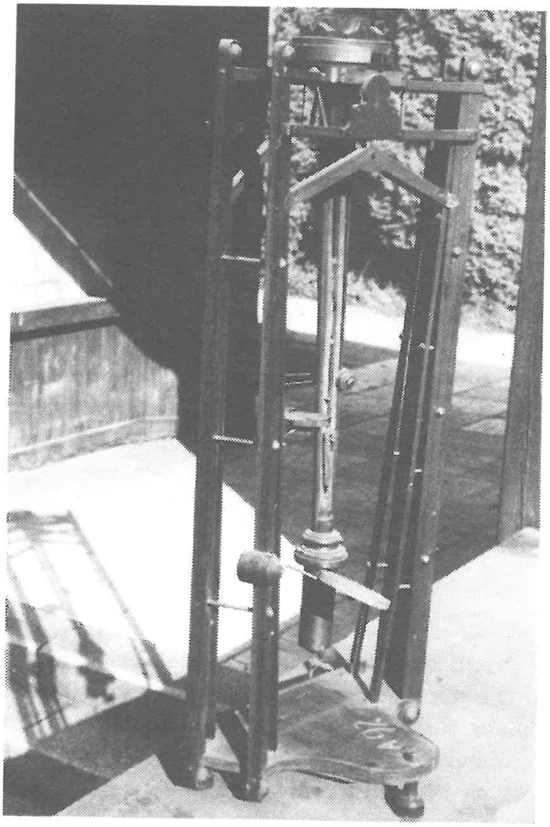

Figure 1 Original seismograph designed by Karl Kreil and built during his stay in Prague (1845-51) (Mining Department of the National Tecnical Museum).

Historic Seismograms and Materials preserved at the Seismic Station of the "Observatori de l'Ebre"

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Introduction

The "Observatori de l'Ebre" is sited at the town of Roquetes, in the Nord-East part of the Iberian peninsula and near the Ebre river delta, its geographical coordinates are 40^o 49.23′ N and 0^o 29.60′ E. It was founded on 1904 by the Society of Jesus, as many other observatories around the world, and its first director was R. Cirera S. I., former vicedirector of the Manila Observatory.

Ebre observatory was devoted, since its foundation up to now, to the study of the Solar Terrestrial physics. Because at the foundation time it was believed that the earth seismicity was related to the solar activity, a seismological section was created. In this line a seismic pavillon was built up and seismographs were provided to record the earth seismic motion. Seismic station has been operated up to now.

Ebre observatory seismological station EBR is the third oldest seismic observatory in Spain, after San Fernando (1898) and Cartuja (1902), both in the south part of the Iberian peninsula. In despite of its singular origin, EBR became an important regional station and up to the seventies it has been together with Fabra Observatory (founded in 1906) in Barcelona the unique station in the Nord-East part of Spain. This makes its records very valuable for studies of the seismicity of the western mediterranean area and the Pyrenees.

From the observatory reports, we know that the seismic motion record at Ebre observatory started already in 1904. The first preserved seismic records date from 1905. From that time up to the present, a really large quantity of seismic records, written materials related to the seismic station and some old seismographs have been preserved. Also, a large amount of printed material from other institutions is preserved in our library. We think the existence at Ebre observatory of such a set of documents concerning the history of seismometry is quite unkown. Next sections will review shortly the main elements of this collection

Seismographs

Since 1904 several seismographs with different configurations have been operating at EBR station. From the point of view of the seismographs, it is possible to divide the history of this seismic station in four main periods, each one is started by a great restructuration of the recording equipment and of the building holding it. First period starts at the foundation of the observatory on 1904 up to 1914, Grablowitz and Vicentini seismographs were operated. In 1914 a great reconstruction of the seismographs room was undertaken and new instruments were added to the recording equipment. Prior to the Grablowitz stopping, Mainka tipe seismographs built at the observatory were setup, two Vicentini seismograph. (Z & E) remained operative and a vertically suspended pendulum recording on the N-S direction was added. Fig. 1 shows the distribution of the seismic pavillon at that time. Normal operation of the seismographs during Spanish civil war became extremely difficult, in 1938 republican army on retreat disabled the Ebre observatory and seismic section suffered from this. Even so, seismic record remained totally stopped for only 3 months (April 6 - July 20). Starting the forties the seismographs room was reconstructed once more and new seismographs installed. Two modified Mainka seismographs and a new vertical pendulum (all built at the observatory) were the standard recorders. These instruments were stopped around 1966; but they are still conserved in their recording site. Fig. 2 shows the seismic pavillon after reconstruction on 1942, we may compare the distribution of the seismographs, hanged on a huge column, from that of fig. 1 where the seismograph were suspended from the walls of the building. Table 1 sumarizes the seismograph equipment and characteristics for these three periods.

The fourth period started in 1966 with the installation of WWSSN short and long period seismograph tipes and last up to the present. As information of this last period is beyond scope of this paper, we will not refer to it anymore. Also, since its foundation, other seismographs and configurations of the equipments have been operated ocasionally. It is planned to publish a more detailed study where these instruments and other details will be described more carefully.

Records

A large quantity of seismic records has been preserved at the observatory. The oldest one corresponds to the earthquake occurred on April 29, 1905 at 01h 46' in the Haute-Savoie region. In fact, this is the oldest seismic record preserved at present in Spain, because older records from San Fernando and Cartuja are lost. The conservation and quality of the records is quite good. Also the series is very complete. A preliminary comparison with the table of the main earthquakes of this century given by Richter (Elementary seismology, 1958) shows the observatory only missed 17 of the 127 events it should record. Most of the lost events correspond to the periods the seismographs were stopped.

Other materials

Beyond the seismographs and seismic records, other important materials for the history of seismometry are kept at the Ebre Observatory. First at all, the Observatory bulletin which contents seismilogical data for years 1910 - 1913, 1921 - 1937 and 1943 - 1951. It contains data on recorded earthquakes, seismograph calibration constants and seismic section evolution (fig. 1 and 2 are taken from the bulletin). These bulletins contain photographic copies of selected earthquake records (mainly the largest earthquakes of this century). Some of the printing plates are still preserved. Besides the observatory bulletin, preliminary seismic readings bulletins were issued regularly on different periods.

Together with the bulletins, old handwritten notebooks detail the day to day operation of the seismographs in different periods. Sparse letters and telegrams between observatories show the seismic section activity.

Finally, the observatory library has a large quantity of seismic bulletins correspond-

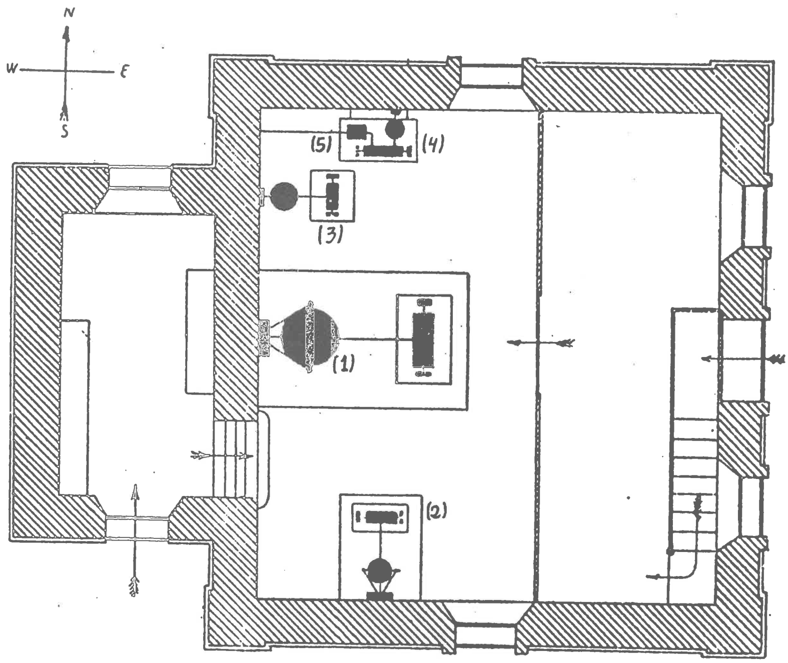

Figure 1: The seismic pavillon distribution from 1914 to 1941: (1) Mainka N-S, (2) Mainka E-W, (3) vertical pendulum N-S, (4) Vicentini E-W and (5) Vicentini Z.

ing to old seismic stations around the world. Also many old articles and books in seismology (e.g. the original report of the State Earthquake Investigation Commission on the April 18, 1906 San Francisco earthquake) are kept. Several of them contains copies of seismic records from other seismic stations around the world. At present, a serious work of reclassification has to be undertaken to allow a best knowledge and use of these materials.

Final remarks

A review of the seismographs, seismic records and other materials preserved at the Observatori de l'Ebre seismic station has been done. Due to its historic importance, further conservation and diffusion among the scientific community of the collected materials should be enhanced. Efforts should be made to improve the classification and knowledge of the contents of the written materials. It will be extremely important, to insure perdurability of the seismic record series, to proceed, as soon as possible, to the microfilmation of the preserved records. Technical collaboration and funds should be provided for these objectives.

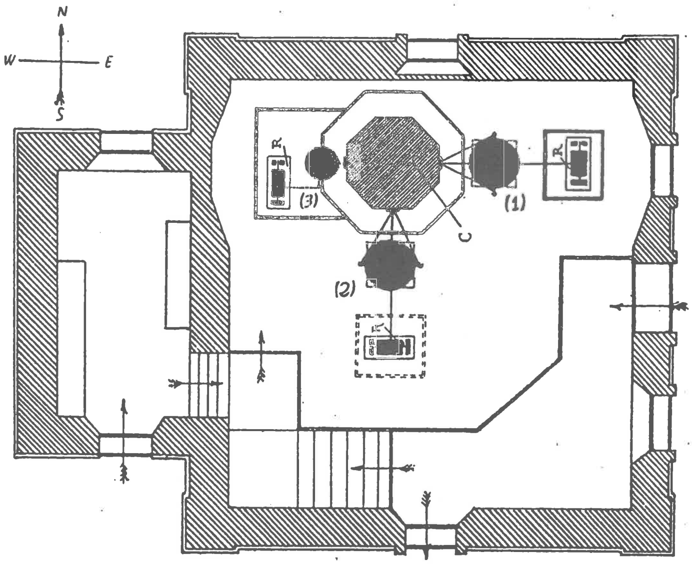

Figure 2: The seismic pavillon after reconstruction on 1942: (1) Mainka-Ebre N-S, (2) Mainka-Ebre E-W and (3) vertical pendulum N-S.

	SEISMOGRAPHS AND RECORDING PERIODS AT OBSERVATORI DE L'EBRE SEISMIC STATION				
Epoch	**Rec. Per.**	**Seismograph**	**Comp.**	**Mass (kg)**	**Nat. P. (s)**
1904	1904-1918	GRABLOWITZ	NE-SW	12	13
	1904-1918	GRABLOWITZ	NW-SE	12	13
-	1904-1936	VICENTINI	Z	50	0.85
	1904-1916	VICENTINI	N-S	100	2.3
1914	1904-1928	VICENTINI	E-W	100	2.3
1914	1914-1940	MAINKA	N-S	1501	14.8
	1914-1937	MAINKA	E-W	157	7.8
-	1915-1941	V. PENDULUM	N-S	316	2.6
		VICENTINI	Z		
1941		VICENTINI	E-W		
1942	1940-1966	MAINKA-EBRE	N-S	1500	15.4
-	1942-1966	MAINKA-EBRE	E-W	1500	10.8
1966	1943-1961	V. PENDULUM	N-S	635	2.5

Table 1: Recording periods and main instruments operated at the "Observatori de l'Ebre" seismic station.

TROMOS: A RESEARCH PROJECT TO REDISCOVER THE HISTORICAL ROOTS OF THE SCIENCE OF EARTHQUAKES

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INTRODUCTION

Instrumental seismology has a long tradition in Italy. In fact, for more than two centuries Italian scientists have contributed to the development of the experimental method in the science of earthquakes.

The relevant quantity of documentation, instruments and observations produced in this period, and especially after the middle of the last century, represents an extraordinary heritage from the historical viewpoint, but also from the scientific one.

Though this premise, in the area of seismological research, as in many others, the neglect and loss of historic material has been in the past a very common occurrence. There are two main reasons that determined whether or not instruments and documentation from the European seismological tradition have survived. The first is in the many changes that have occurred in the network of observation, reducing the role and the importance of individual Observatories. The second consists of the particular nature of the development of the instrumentation, that often involved the reuse of parts of older instruments.

SCIENTIFIC PURPOSES OF THE TROMOS PROJECT

At the beginning of 1990 the Istituto Nazionale di Geofisica (ING) started the two year TROMOS project to research, recover, restore and re-evaluate the historical heritage of scientific earthquake observation in Italy (Fig. 1). The name of the project refers to one of the most fruitful periods in early seismology.

In 1872, Timoteo Bertelli, one of the pioneers in this field, drew on the Greek word tromos to name the instrument he had made to observe and measure the tremors of the Earth: the tromometer.

The main aims of the project were:

- the complete listing of the centres of meteorological and seismic observation operating in Italy from the eighteenth century to the present day;
- the restoration of some of the most important historical seismic instruments in Italian centres;
- the reproduction of the historical seismograms of the major Italian earthquakes recorded in this century both in the Italian and European centres;
- the re-evaluation of the historical and scientific results of the research carries out so far.

Why should the seismological community be interested in the recovery and protection of this heritage?

The undoubted usefulness of the modern recordings for theoretical and applied studies is seriously limited by the chronological span of the standard seismic networks - to small as far as the return period of large earthquakes (amounting to tens or even hundreds of years) is concerned. Therefore, the only way to obtain useful indications about the characteristics of the origins of big earthquakes such those that occurred in San Francisco (California)

in 1906 or in Messina (Southern Italy) in 1908, is to look back at the historical recordings.
Nevertheless, it would not be possible to reconstruct the history of seismology through the instruments alone, nor even a history of the instruments themselves. Without the use of historical documentation it would be impossible to document and analyse historically and scientifically the long period of experimentation with various types of instruments, often very distinct in shape and function. This can only be done through a study of the historical sources: publications, manuscripts, instrumental observations and recordings, letters between scientist, etc.

RESULTS OF THE TROMOS PROJECT

A specific system of indexing has been created for the storage of information gathered from the systematic collection and analysis of published and unpublished contributions discovered in the course of the research.
The data bank of the scientific observation in Italy includes bibliographic, descriptive and illustrative information related to instruments, observations, scientists and instrument makers.
At the present time the data bank contains more than 5500 biblio- graphic and documentary sources giving information about: over 1000 meteorological and seismic observation centres, 600 instruments and 250 scientists and instrument makers. More than 10,000 historical and scientific sources have been identified and analysed including: scientific publications, recordings in manuscript, seismic bulletins and letters between scientists. Besides this storage system, the data bank includes other menus capable of producing a synthesis. Thus, it is possible to enter all the indexed information discovered during the research in any order, and then to retrieve it according to individual requirements.
In the second phase of the project more detailed analysis has been carried out on various kind of information. More than 60 historical observatories or centres with tradition in recordings have been visited. Of the 600 instruments listed in the data bank, more than 150 have been identified and photographed in the Italian centres visited. Much material has been found in observatories still functioning, but in other cases just photographs or documents, published or in manuscript, remain and are now conserved in other sites.
In addition, the historical development of 126 instruments and the scientific biographies of 120 scientists and instrument makers have been described in depth.
The TROMOS project has so far carried out the restoration of 25 instruments. Among them, the entire collection of seismic instruments of the Collegio "alla Querce" in Florence, the portable tremorscope of De Rossi (1880) and the original prototype of the famous electromagnetic seismograph of Luigi Palmieri (1856).
One of the most important tasks of the project was to find, catalogue and microfilm the historical seismograms preserved in observatories in Italy and in European centres where Italian earthquakes were recorded. The wide-range and systematic research undertaken has made it possible to identify large collections of Italian seismic recordings, going back to the early 1880s, but appearing with greater continuity since the beginning of the twentieth century. After careful analysis of all the major experiments in the international field as far as the reproduction of historical seismographs on microfilm is concerned, it has been decided to use the standard 35 mm

format, as being the system giving the best quality and legibility with the least deformation of the seismic signal when reproduced on paper.
The project also includes some initiatives of revaluation, carried out through exhibitions, publications, audiovisual presentations etc. In connection with this, three volumes have been published and two exhibitions have been organised.

ANALYSIS OF HISTORICAL RECORDINGS OF THE 1908 MESSINA EARTHQUAKE

The December 28, 1908 Messina earthquake was the most catastrophic occurred in Italy in this century, or even in the last five centuries. Such event drew the attention of many famous seismologist at that time and is still subject of investigation at our days. As an example of the still actual validity of historical recordings, it appeared interesting to try modern methods of analysis to the exceptionally clear seismograms of this earthquake contained in the archives of the Observatory of Rocca di Papa. We put our attention to the seismograms obtained by the dual speed Agamennone "seismo-metrograph". Due to its low magnification (G=14), this instrument was not saturated by the very large amplitude of the waves at a distance of 450 kms from the epicenter. The two horizontal components of the seismograms were manually digitised on a digitising table and the data so obtained were processed by means of computer programs specifically written at the ING. After correction for base line, chart speed variation, stylus length, instrument response, etc. the program computed the Fourier spectra of the ground movement (acceleration) recorded at the station site. Making use of well established algorithms it was possible to compute a rough estimate of the seismic moment. We obtained:

Mo = 5.5 1.E26 dyne cm from the NS component
Mo = 7.2 1.E26 dyne cm from the EW component

These results are slightly larger than the value obtained from the analysis of geodetic measurements carried out in 1909.

CONCLUSIONS

One of the main aspects of the TROMOS project is the multidisciplinary nature of the approach and its chronological and geographical breadth. Italian seismologists have established a fruitful collaboration with historians and historians of science.
This has led to an experiment that is probably unique of its kind. It has been possible to retrace the historical and geographical itinerary of the scientific, human and institutional events in one of the most fascinating and complex stories of instrumental studies of earthquakes.

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THE TROMOS 1990-91 PROJECT

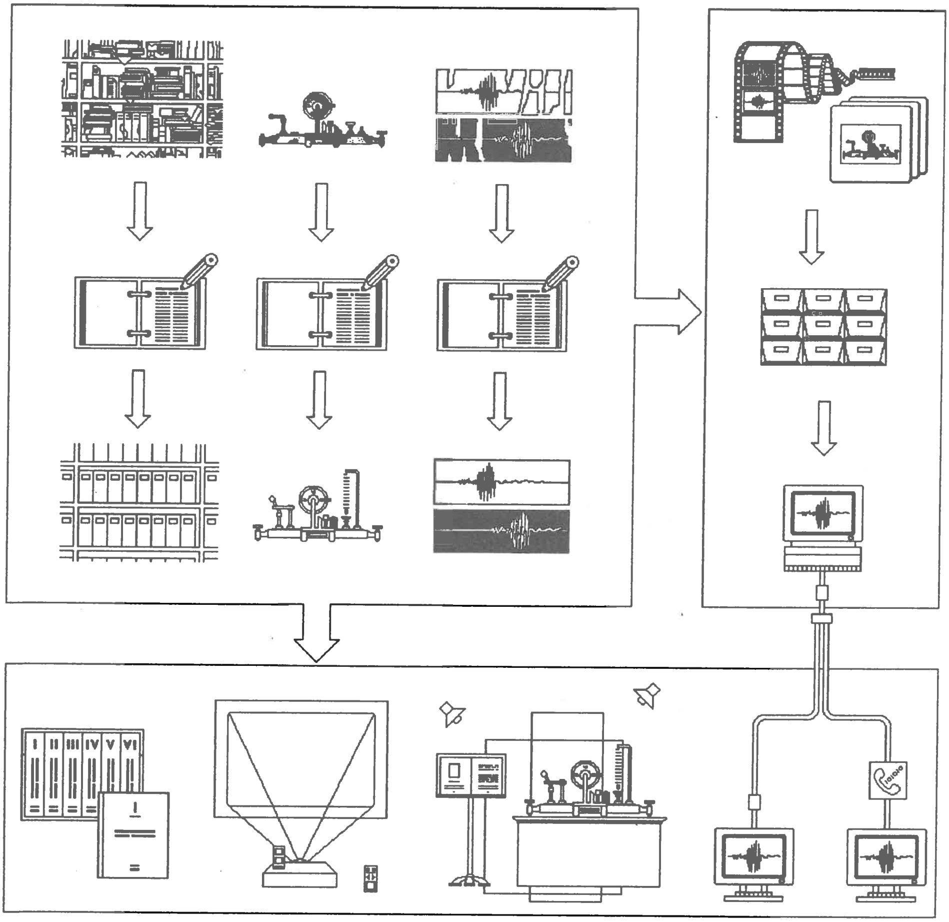

Figure 1 Flow chart of the TROMOS project for research, recovery, restoration and re-evaluation of the historical heritage of scientific observation of earthquakes in Italy (XVIII-XX century).

LAMPS, BIRDS AND TROMOMETERS: THE STUDY OF MICROSEISMS AND SAFETY IN MINES

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INTRODUCTION

In the second half of the nineteenth century the development of industry, particularly relating to metal, and the overall increase in fuel consumption for civil use made it necessary to change from wood coal to fossil coal as a source of energy, with the consequence that the more coal was used, the deeper it was necessary to dig (Landes D.S. 1974).

Following the terrible explosions in the British mines, in early December 1875 an anonymous article appeared in the English review The Engineer. The author, without any reference to Italian studies on microseismology, suggested that the imperceptible movements of the soil were the probable cause of the dislocation of the coal seams resulting in the release of inflammable gas. The existence of 'movements so slight as to be imperceptible' was 'well-known' to the mining engineers. In this article, for the first time, the minute vibrations of the earth were considered alongside the research of the seismologists and particularly those of Alexis Perrey.

Great earthquakes and imperceptible movements were, in the opinion of The Engineer, all due to the same principle, that is to the great compression of the interior of our planet and to the sinking of the external crust over the interior that once again is compressed. (The late colliery...,1875).

Thus we can see that people were thinking about this problem concerning the gas emissions while the job of monitoring these emissions remained the responsibility of the gas indicators in use at that time. One of the methods most commonly used was the small cage containing a canary, more sensitive than man to the presence of carbon monoxide in the air.

From the 1830s onwards limited use was made, to measure fire-damp in the galleries, of the expensive Davy lamp. Despite the fascination of hypotheses, it was well known that 'one of the most important points in mining is ventilation, that is the general method of obtaining a renewal of air in the underground excavations' (Boccardo G. 1882). Engineers had been only too aware of the serious economic burden presented by such a system since the early days of modern mining (Agricola G. B. 1556) (Fig 1).

TROMOMETERS AND SAFETY IN MINE

An attentive reader of the scientific journals of Europe like Michele Stefano de Rossi could not fail to notice this involuntary confirmation from the English engineers of the theory of the endogenous origin of earth tremors - a theory much disputed in Italy where critics tried to deny it.

De Rossi, on the other hand, was convinced as a result of scientific contacts with Timoteo Bertelli who had begun regular observations in Florence in 1870, using instruments he called tromometers that could measure the small and imperceptible movements of the earth.

De Rossi was thus quick to point out the connection between the repeated explosions in the British mines and an extraordinary period of microseismic activity observed from the recordings of the instruments sited in Rome and at Rocca di Papa (de Rossi M.S. 1875).

The theories put forward by The Engineer and immediately embraced by de Rossi were set aside for a good eight years, the idea of the influence of barometric depressions on gas emissions finding greater favour with the scientists and mining engineers (de Chancoutrois B. 1883). It was thanks to the network of contacts between the Italian and the French scientists that de Chancoutrois, the inspector general of the Corps des Mines, took part in the Geology Congress held in Bologna in 1881.

Here he was able to appreciate the great advances made by the Italian scientists in the area of seismographic instrumentation. At the same period, in France, the work of d'Abbadie and Bouquet de la Grye was improving the instruments used by them to observe the small movements of the earth's crust. A new series of destructive explosions in Britain, France and Germany led de Chancoutrois to speculate on 'the possibility of drawing from this type of observation a practical method of forecasting, to some extent, the emissions of fire-damp' (de Chancoutrois, 1883).

The intention of the inspector general of the French Corps des Mines was to install seismographic instruments at the entrance to the mine shafts that, 'by indicating the renewal of activity in the internal movements of the earth, would provide information that would alert the miners to the need to double the care and precaution taken. This first step would no doubt be followed by other more important methods still to be developed' (de Chancoutrois, 1883).

The French Minister of Public Works, supporting the ideas of de Chancoutrois, sent him in May 1883 on a study mission to Italy together with the mining engineers Chesneau and Lallemand.

The French engineers were received by Michele Stefano de Rossi, director of the Archivio Centrale Geodinamico at the Reale Comitato Geologico of Rome, responsible at that time for a national seismic service. They visited the most important observatories in Italy and met scientists like Timoteo Bertelli, Filippo Cecchi, Francesco Denza, Luigi Palmieri, Pietro Monte and Orazio Silvestri.

The research into archives and libraries undertaken by the TROMOS project of the Istituto Nazionale di Geofisica of Rome, has resulted in a full picture of all aspects of this event.

This study mission was not without its consequences both in France and in Italy. The French delegation produced a report of the visit, deeming the mission and the seismological documentation collected during the course of the visit to be of great interest.

Together with the report were descriptions of many instruments perfected by Italian seismologists (Fig.2), with particular reference to those beginning to be used in various Italian sites for microseismic observations. Later the French government acquired a normal tromometer and a microseismograph which were installed in the Ecole des mines in Paris and a second normal tromometer for the Ecole des maîtres mineurs in Douai in the mining area of Valenciennes. Daily observations with the Douai tromometer began on a regular basis in February 1886 and were compared with the barometric measurements and the emissions of fire-damp detected by Pieler's lamp. The French engineers were of the opinion that such experiments should continue since 'the comparative examination of the diagrams obtained shows overall a marked correlation between the three categories of phenomena' (Chesnau G. 1886).

Despite this auspicious start, the experiments relating to the coincidence of baroseismic activity and the emissions of fire-damp did not come to anything. In 1941 Haton de La Goupillière, inspector general of the French mines, was to write: 'The observations are in any case still too few and too uncertain for us to consider the problem solved' (de La Goupilliere H. 1941).

CONCLUSIONS

In Italy, a country rich in earthquakes and poor in mines, the visit of the French delegation provided Michele Stefano de Rossi with just the ammunition he wanted to back up his argument for the need for a national geodynamic service, so often attacked by other Italian scientists. Despite this aura of international prestige, however, de Rossi was not able to avoid other problems, including political ones, which were to prevent him from continuing his work as director of the Italian network of seismological observatories (Letter from the Director of the Observatory and Central Geodynamic Archive. . . 1887). Tromometers disappeared from the world of the coal-mine. To protect the underground passages and the miners, as recently as the 1930s, new types of lamp and detector were used, while 'canaries, though more sensitive to carbon monoxide poisoning than men, are less used than formerly, but the Bureau of Mines rescue crews often carry them' (Peele R. 1937).

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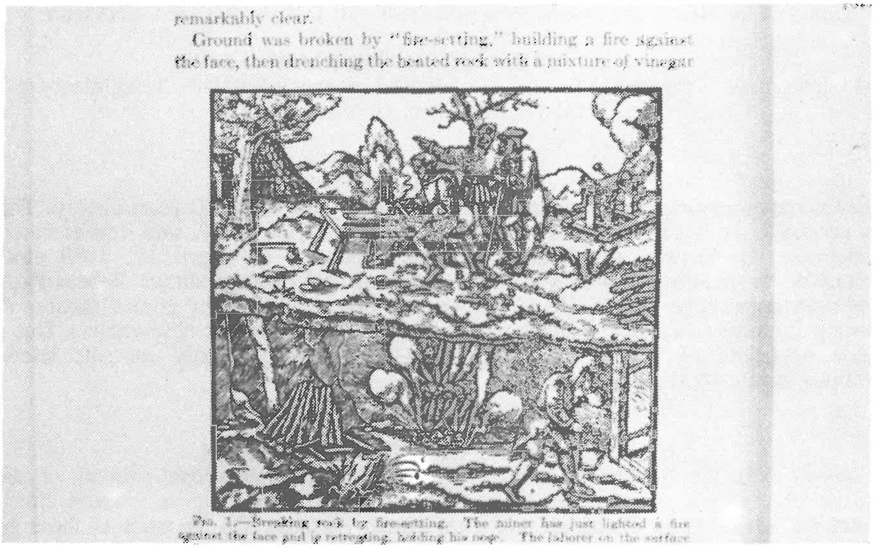

Figure 1 Breaking rock by fire - setting (from Agricola, 1556)

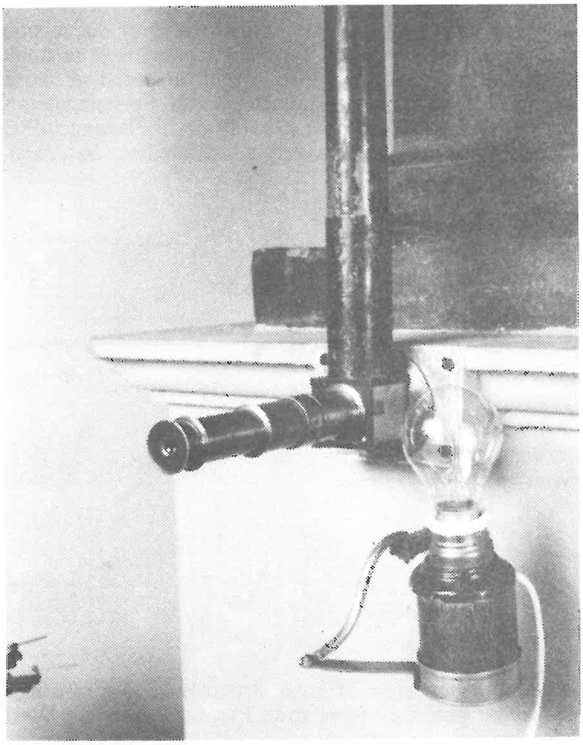

Figure 2 The Bertelli's normal tromometer at the "alla Querce" Observatory of Florence. The instrument was recently restored in the framework of the Tromos project.

DEVELOPMENT OF POTSDAM STATION AT THE TURN OF CENTURY

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INTRODUCTION

Seismological observation and research at Potsdam have more than 100 years history. They are closely related to the work of famous geodesists and geophysicists like E. von Rebeur-Paschwitz, F.R. Helmert, O. Hecker, G. Gerland, and O. Meissner. On April 17, 1889 observing deflections of the plumb line with a specially designed horizontal pendulum Rebeur-Paschwitz detected unexpected large signals. His idea to explain these deflections by ground motions caused by a strong Japanese earthquake was the moment of birth of teleseismic observations. Due to the bad state of health of Rebeur-Paschwitz during the next years only sporadic teleseismic observations were carried out at Potsdam.

ESTABLISHMENT OF POTSDAM STATION

The idea of Ernst von Rebeur-Paschwitz (1895) to install an international network of identical earthquake observating stations has really influenced seismology up to present time, and especially the development of the seismological station Potsdam. On the basis of these general rules Gerland (1904, 1905) worked out a detailed plan of a hierarchic network of seismological observatories in Germany containing 12 first order observatories as well as 27 second order stations. Potsdam station was chosen to be of first order. The Royal Prussian Geodetic Institute was the host institution for this observatory.

F.R. Helmert, director of the Institute, and O. Hecker, head of the seismological department, have strongly supported the plan to install at Potsdam a permanent seismological observational facility. Nearby the main building of the Geodetic Institute a special seismometer house had been set up. Figure 1 shows the drawing of the seismometer house. Seismometers were installed inside the inner building separated from the outer one to avoid environmental influences on recordings. Seismometers were placed on a massiv pillar having a separate deep basement.

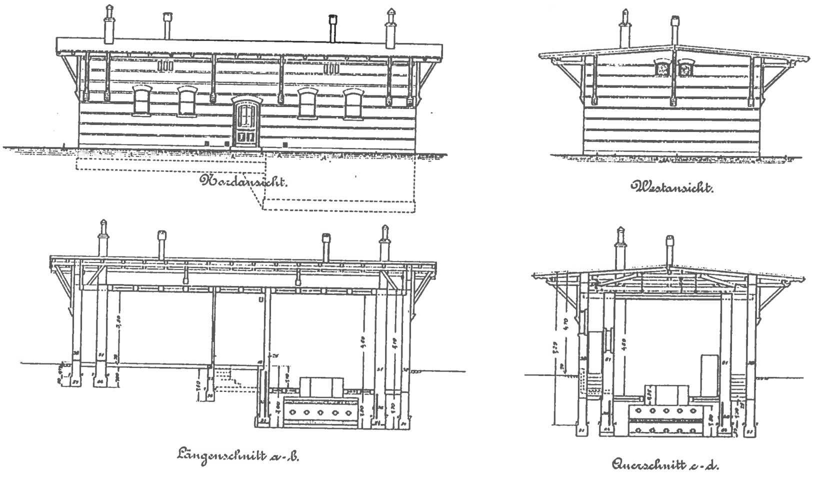

Fig. 1. Drawing of the seismometer house of Royal Prussian Geodetic Institute at Telegrafenberg, Potsdam. In the upper part the views from the North and the West, in the lower part cross-sections are shown.

On the first of April 1902 the seismological station Potsdam (POT; 52.380 N, 13.068 E) was opened. First instruments were horizontal pendulums based on the construction of Rebeur-Paschwitz. The most advanced seismometer of that time, the Wiechert-seismometer was installed within the beginning stage of the station. On the 13th of October, 1903 the astatic Wiechert horizontal pedulum has been introduced into permanent exploitation. The main data of the instruments used at Potsdam station at this time are given in table 1.

Table 1. Characteristics of seismological equipment of Potsdam station.

	Horizontal Pendulum	Wiechert Astatic Seismometer
mass	85 g	1100 kg
natural period	18 sec	about 14 sec
magnification	36	130 - 205
recording speed	36 cm/hr	64 cm/hr

Timing was provided by a special clock, which has been compared regularely with the normal clock of the Geodetic Institute. All recorded and evaluated earthquakes as well as parameters of the instruments and events influencing recording have been documented in the station bulletin "Seismometrische Beobachtungen in Potsdam" (1903-1954).

OPERATION OF THE WIECHERT-SEISMOMETER

Regular seismological observations by the horizontal Wiechert-seismometer started on October 13, 1903. The determined seismometer parameters were also published by the station bulletin. Figures 2 to 4 show the changes of the parameters of the N-S and the E-W components of the Wiechert over time.

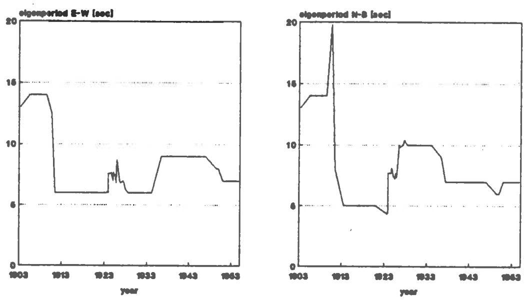

Fig.2. Change of the eigenperiod of the Potsdam Wiechert-seismometer.

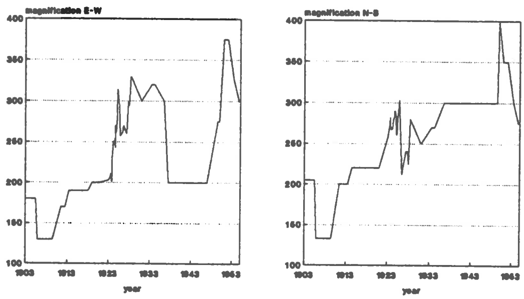

Fig.3. Change of the magnification.

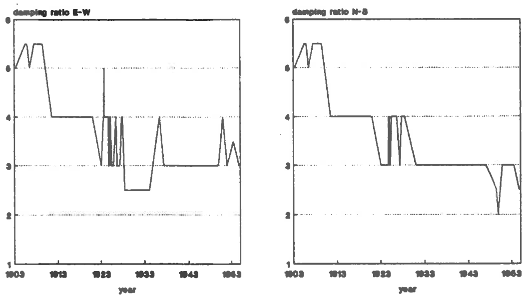

Fig.4. Change of the damping ratio of the Wiechert-seismometer.

These figures document that large changes and deviations from normal values have occured in 1910 and in the 1920's. The first anomaly is due to a long time period without determination of seismometer constants (November 1905 - September 26, 1910). During the First World War and immediately after a stable seismic service has been provided by the work of the staff of the Institute. The second period of unstable seismometer working has been caused by financial problems of the Institute. Nevertheless, in 1926 the problems of seismic service have been solved. After the installation of two horizontal seismographs of the Galitzin-type a reconstruction of the Wiechert-seismometer took place. Figure 5 shows the interior of the seismometer house at this time.

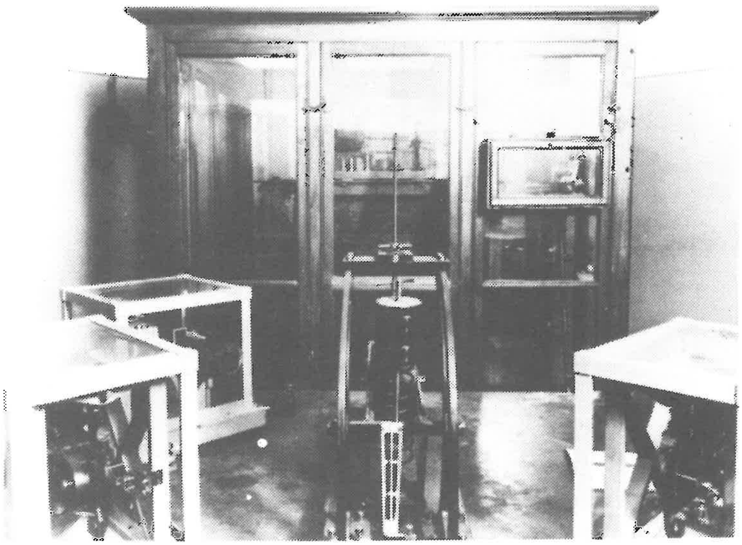

Fig.5. The 1100 kg astatic Wiechert-seismometer of the Potsdam seismological station. In front of the Wiechert on the pillar there are horizontal seismometers of the Galitzin-type and a vertical Wiechert-pendulum.

The Wiechert horizontal seismograph of Potsdam station was in regular operation until the closing of the station on the 3rd of September, 1954. During its operational period 529 strong earthquakes with magnitudes equal or larger than 6.0 were recorded.

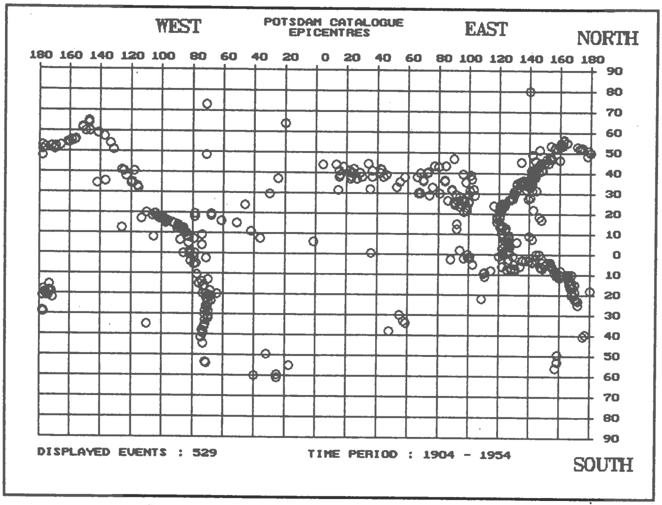

Fig.6. Distribution of epicenters of strong earthquakes (M>6) recorded by the Wiechert-seismometer of Potsdam station (1904-1954).

After closing Potsdam station the Wiechert seismometer was moved to a permanent exhibition of seismological instruments at Ranis castle (Thuringia).
Seismograms of Potsdam station are preserved up to present. They have been incorporated into the international IASPEI-project of microfilming of historical seismograms. For the strongest events magnitudes were calculated (Kowalle, Thürmer, 1991).

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