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Federal Institute of Technology, Zürich, Switzerland
No. 101

I.U.G.G.
International Association of Seismology
and Physics of the Earth´s Interior

European Seismological Commission

Activity Reports 1984-1986
and
Proceedings of the XX.General Assembly 1986 in Kiel

Edited by:
D. Mayer-Rosa
J.M. Van Gils
H. Stiller

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Preface

The European Seismological Commission´s prime task is to promote the science of seismology in Europe and in the countries bordering the Mediterranean sea. This is accomplished by consensus of titular members in 37 countries and by active and continuous work in eight subcommissions and different temporary working groups. The biennial general assemblies of the ESC, organized alternately in the eastern and western parts of Europe, provide a unique opportunity for scientists to communicate across geographical and political borderlines. One of the most important tasks of the ESC in future is to provide a platform specially for young scientists to cooperate in international working groups and multinational projects.

The meeting in Kiel in August 1986 was organized jointly with the European Geophysical Society. It provided seismologists with direct contact to a larger geophysical community. The ESC gratefully took advantage of the sponsorships by the German Research Association and the State of Schleswig-Holstein. The ESC is specially indebted to Prof. Rolf Meissner and the local organizing committee in the Institute of Geophysics of the University of Kiel for their work devoted to the meeting.

A number of events made this year a remarkable one. First, it should be remembered, that the ESC celebrates the 35th anniversary of its foundation this year . Furthermore, three members left the ESC bureau after successfully serving the Commission for a long time-period: Prof. Heinz Stiller, Potsdam, president since 1982, Jean M. Van Gils, Brussels, general secretary since 1976 and Prof. Augustin Udias, Madrid, vice-president since 1982. Their place is taken by Prof. Carlo Morelli, Trieste, Dieter Mayer-Rosa, Zürich and Paul Burton, resp. Prof. Ludmil Christoskov, Sofia, is the new adjoined secretary. Prof. Stiller as past president is a member of right in the bureau at least until the next election.

A considerable amount of activities in the ESC has been directed by J.M. "Théo" Van Gils during the past 10 years. He was elected as adjoined secretary in 1964. Since then he co-organized with general secretary Elie Peterschmitt the general assemblies 1966 in Copenhagen, 1968 in Leningrad, 1970 in Luxembourg, 1972 in Brasov, 1974 in Trieste, and 1976 in Cracow. As elected general secretary he was responsible for the general assemblies 1978 in Strasbourg, 1980 in Budapest, 1982 in Leeds, 1984 in Moscow and finally 1986 in Kiel. The ESC sincerely owes thanks to Théo for his long-lasting commitment for the commission.

D. Mayer-Rosa, secretary general.

Composition of the ESC-Council

According to the statutes, the Council is the ruling body of the ESC . For the time period 1986 -1988 it consists of:

The Bureau:

President	C. Morelli
Vice-President	I. Nersesov
Vice-President	P. Burton
Secretary general	D. Mayer-Rosa
Adjoined Secretary	L. Christoskov
Member by right	H. Stiller

The Subcommission chairmen:

SC 1	V. Karnik
SC 2	H. Aichele
SC 3	A. Udias
SC 4	E. Hjortenberg
SC 5	H. Stiller
SC 6	C. Morelli
SC 7	H. Berckhemer
SC 8	A. Lopez Arroyo

The titular members:

Albania	E. Sulstarova, Tirana
Algeria	M. Benhallou, Alger
Austria	J. Drimmel,Wien
Belgium	M. DeBecker, Bruxelles
Bulgaria	L. Christoskov, Sofia
Czechoslovakia	J.Vanek, Praha
Denmark	J. Hjelme, Kopenhaven
Egypt	M. Maamoun, Cairo
Finland	H. Korhonen, Helsinki
France	M. Cara, Strasbourg
F.R.Germany	J. Wohlenberg, Aachen
German D.R.	H. Stiller, Potsdam
Greece	J. Drakopoulos, Athens
Hungary	E. Bisztricsany, Budapest
Iceland	R. Stefansson, Reykjavik
Ireland	A.W.B. Jacob, Dublin
Israel	A. Shapira, Holon
Italy	C. Morelli,Trieste
Jordan	Z. El-Isa, Amman
Lebanon	J. Plassard, Ksara
Luxembourg	J. Flick, Luxembourg
Morocco	D. Ben Sari, Rabat
Monaco	N. Bethoux, Monaco
Netherlands	R. Ritsema, DeBilt
Norway	S. Mykkelveit, Kjeller
Poland	R. Teisseyre, Warsaw
Portugal	L. Mendes Victor, Lisboa
Rumania	L. Constantinescu, Bucharest
Spain	J. Mezcua, Madrid
Sweden	O. Kulhanek, Uppsala
Switzerland	D. Mayer-Rosa, Zurich
Tunisia	M. Allouche, Tunis
Turkey	A. Neclioglu, Ankara
United Kingdom	R. Pearce, Cardiff
USSR	I.L. Nersesov, Moscow
Yugoslavia	D. Skoko, Zagreb

Bureau meeting on 20. Aug. 86, 14:00 - 17:00

Present: Stiller, VanGils, Mayer-Rosa. Invited: Meissner and Berckhemer
Prof. R. Meissner, chairman of the local organizing committee, explains the premises and special installations for the joint EGS/ESC meeting in Kiel. The third circular with the entire program is distributed.The bureau is concerned about the printing delay of the **proceedings of the Moscow Meeting 1984**. A preliminary preprint of the business part of the proceedings is handed out to the bureau. For the preparation of the elections and the selection of candidates an **election committee** was appointed. It consists of R.Ritsema, J. Vanek, J.M. VanGils and E. Hurtig. For reason of time, it was decided to schedule **the activity reports of the subcommissions** for the different sessions of the subcommissions and not in the opening session. The general opinion is, that **joint meetings with EGS should be supported**, but seismological sessions in such meetings should primarily be arranged within the ESC-program sections. It was taken notice, that the **time of duty for subcommission chairmen** normally should not exceed 8 years, according to the valid regulations. This means, that in 1988 several subcommissions have to deal with this point. Finally, President Stiller declares the **XX. General Assembly of ESC opened.**

Council meeting on 20. Aug. 86, 16:15-18:00

Present: Aichele, Berckhemer, Hjelme, Mayer-Rosa, Morelli, Pearce, Ritsema, Shapira, Stiller, Van Gils, Wohlenberg.
The ESC **working group on statutes** was formed during the XIX. GA 1984 and consists of Hjelme (Denmark) as chairman, L.Christoskov (Bulgaria) and J.M.VanGils (Belgium). Hjelme presents a first draft of modifications for the regulations. As a general rule, only absolutely necessary revisions to the existing regulations are planned. The following major changes are discussed: 1. To change "titular members" in "national representatives". It is believed, that this would be a more flexible solution, but the strong personal ties are lost. 2. The relationship between the European Mediterranean Seismological Centre (Strasbourg) and the ESC is demonstrated by mutual installation of representatives. Since no final draft of new regulations could be presented in Kiel, the president extended the mandate for the group until the General Assembly 1988.

Opening Plenary Session on 21. August 1986, 9:00-10:00

Address by the ESC President

"Dear Colleagues, I am very glad to welcome you at the twentieth General Assembly of the European Seismological Commission, the only regional commission of the International Association of Seismology and Physics of the Earths Interior of the International Union of Geodesy and Geophysics, here in Kiel, Federal Republic of Germany.

I am noting with pleasure that so many European Seismologists and also colleagues from overseas have followed the kind invitation of the University of Kiel and the Geophysical Institute of this highly reputed research and educational institution. The Geophysical Institute of the University of Kiel, the local organizing committee with its chairman Professor Rolf Meissner and the bureau of the European Seismological Commission have done their best to prepare and to organize the twentieth General Assembly which shares some meetings with the European Geophysical Society. They have done and will continue to do a great service to all of us and our commission. On behalf of all the participants I like to express my hearty thanks.

It is a great honour and pleasure for me to welcome the representatives of the Bundesland Schleswig-Holstein, of the city of Kiel, and of the University of Kiel. I am welcoming Prof. Robin Adams, the Secretary General of our mother association IASPEI. Furthermore, it is a great pleasure for me to welcome representatives and members of the European Geophysical Society, the International Lithosphere Programme, the Commission of the European Communities, and other organizations.

The contact, cooperation and the joint organization of General Assemblies of the ESC with other scientific associations, societies or organizations are highly welcomed. The twentieth General Assembly is marking an important anniversary in the life of our commission.There are only few among us, for example Elie Peterschmitt, who is especially welcomed today, who joined the first General Assembly which was held in 1952 at Stuttgart, Federal Republic of Germany. This first meeting had been organized by Prof. Hiller one of the fathers of our commission.

Rome, Vienna, Utrecht, Alicante, Helsinki, Jena, Budapest, Copenhagen, Leningrad, Madrid, Luxembourg, Brasov, Trieste, Cracow, Strasbourg, Budapest, Leeds, Moscow, and now Kiel followed to host our General Assemblies and to set milestones in the development and history of the European Seismological Commission.This history has been traced and written down in such a brilliant and attractive manner by our Secretary General, Professor Van Gils, and published with the support of the Academy of Sciences of the German Democratic Republic by the Central Institute of Physics of the Earth at Potsdam.
37 countries are represented in the European Seismological Commission including also countries along the southern and eastern border of the Mediterranean Sea. During the 34 years since the founding of our commission, many new ideas, programmes and projects have developed in seismology. Some subcommissions and working groups were reorganized in the past in order to keep our commission up to date and flexible. But, I think the two basic ideas of our commission are still alive as 34 years ago:

- At first our commission has to study European seismological problems. The European region can be understood as a unique textbook for seismological and related geo-scientific problems. In a relatively small area quite different tectonic and seismogenetic units are bordering. The complexity is rather high. There are highly mobile tectonic chains in the Alpine region, consolidated hercynian belts and platforms, the Caledonides as well as proterozoic platforms and shields. Strong lateral variations of the thermodynamic conditions and the physical properties within the Earths crust and upper mantle have been observed and provide us with a key to understanding the tectonic development and recent seismicity pattern in Europe. Dense population and highly sensitive buildings and industrial facilities add to the challenge for detailed seismological studies.

- The second basic idea has been and continues to be that our commission is aimed at promoting collaboration and co-operation between seismologists from different European countries, countries which belong to different social and political systems. Most of the European countries are small. International cooperation is indispensable, the more so since tectonically controlled seismic activity and hazard is not confined to national boundaries.

Therefore, the European Seismological Commission will continue to play an important role in promoting cooperation between European Seismologists and in ensuring mutual understanding and peaceful coexistence amongst the peoples of our continent. Our Commission should, therefore, continue to be guided by these ideas of its founding fathers.

I wish all of you interesting and fruitful discussions. Thank you for your attention."

In memoriam:

Alois Zatopek

On Saturday, June 22 1985, the scientific world and more particularly the seismological community lost one of its prow figures as our Colleague Alois Zatopek passed away at the age of 78 years. He was a world-wide known man and his long scientific career has been enameled by several distinctive rewards as the Golden Medal of the Karlovy University, the Golden Tablet of the Academy of Sciences of Czechoslovakia, the Kepler-Medal and the Copernicus-Medal of the Czechoslovakian Ministry of Culture. Aside all these national distinctions he also was honoured by foreign rewards as the Euler-Medal of the Academy of Sciences of the U.S.S.R. and the Silver Medal of the Republic of Macedonia for his participation in the works undertaken after the Skopje-earthquake in 1963. He acted also several times as expert during the missions organized by the UNESCO. For what concerns Europe, more specially, as soon as Czechoslovakia became a member of the European Seismological Commission (E.S.C.) in 1956, Alois Zatopek was appointed as the Titular Member of his country and, officially, remained in this function up to the Moscow-meeting (1984), although he gave procuration to the compatriot for the last meetings. As national representative our late Colleague deployed many activities among which his work done in the Subcommission on Microseisms and in the special Working Group of the Carpatho-balkanic Region. For this part of Europe he worked very efficiently and succeeded, in 1964, to create and chair the new subcommission "Seismological Investigations in the Carpatho-balkanic Region" covering the different fields of seismology. Beside, he was very active too inside the special working group on the "Synthesis of Explosion and Upper Mantle Data" and acted as "officer de liaison" between the European Association of Earthquake Engineers and the E.S.C. All these activities were highly appreciated by his European Colleagues who appointed him, in 1959, as Vice-President. Three years later, they elected him as President of the E.S.C. and re-elected him in 1964 for the same

functions. But Alois Zatopek not only was that cold scientist. Apart from his knowledge, he also was a warm-hearted man. This can be demonstrated by all his students: all of them considered him rather as a father guiding his pupils on the way of Science than as a professor dominating the matters taught. On the other hand, he imposed sympathy on and from everyone. Everybody was impressed by that cheerful face that invited to become friends immediately. Only those who answered this invitation are enabled to testify how gentle and warm his receptions were. An evening spent at his place not only consisted in nice meals and profession talks. It was also illustrated either with a lot of self-made slides concerning his missions or by a cello-concert as our Colleague was a nice musician too. Some of us even enjoyed such a private concert at the "Carolinum", the ceremony-hall of the Charles University. Outside the quality mentioned as scientist, teacher and friend, he was a tender husband and father. Wherever he went his wife and daughter were always in his mind.The European Seismological Commission mourns the decease of Academician Alois Zatopek and expresses its sorrowful sympathy to his family.
J.-M. Van Gils, Brussels

Dezsoe Csomor

Deszsö Csomor received his M.S. degree in mathematics and physics from Peter Pázmány University, Budapest in 1942. He received his Ph.D. degree in Seismology in 1974. He spent 36 Years at the Hungarian Seismological Institute. His research interests include earthquake engineering, mainly the methods of seismicity determination. He retired in 1978, and died in 1984.
E.Bisztricsany, Budapest

Maximilian Toperczer

Austrian geophysicists are mourning for a prominent representative of their science: Professor Dr. phil. Maximilian Toperczer-Toporcz, corresponding member of the Austrian Academy of Sciences, passed away on 23 November 1984 at the age of 84 years. After his university studies, Professor Toperczer was working in the scientific service of Zentralanstalt fuer Meteorologie und Geodynamik in Vienna for many years, finally as head of the Geophysical Department. In 1949 he obtained the Venia legendi (lectureship) at the University of Vienna in the subject of geophysics. Owing to his scientific achievements, in 1964 Professor Toperczer received a nomination at the University of Vienna, this being the first academic chair for geophysics in Austria, which he kept until his retirement in 1971. As a teacher, he provided his students, some of whom have already taken up academic careers, with a profound knowledge of their subject.The late Professor was closely connected with the European Seismological Commission: he was Titular Member until 1968 and very much interested in all events of our community until shortly before his passing away. Grateful memories of Professor Toperczer will always remain in our minds.
J. Drimmel, Wien

Dragutin Prosen

Professor Dragutin Prosen, active member of the European Seismological Commission, died on February 18th, 1984.He was born at Ilirska Bistrica, in Slovenia, on July 24th, 1907. In 1928 he finished the Military Academy, and in 1936 graduated at the Military School of Geodesy. It was in 1930 that the first became concerned with geophysical research, and over the period 1938-39 he completed his specialization in geophysics at Potsdam, Vienna and Budapest. During the Second World War, Professor Prosen was held in captivity, but in 1943 he escaped to Switzerland. and thence to France, where he participated in the work of the War Mission of the Yugoslav Peoples Army. On his return to Yugoslavia in 1945, he became an organizer of research in applied geophysics. In spite of the difficult times of the post-war years, it was necessary to achieve the conditions for the normal conduct of this work, for which both equipment and staff were needed. For this reason, Professor Prosen spent all the post-war years in the educating and training of young researchers in the field of applied geophysics. Over 150 young geophysicists graduated at his Department of Geophysics at the Faculty of Mining and Geology in Belgrade, where Professor Prosen held the position of Dean of the Faculty several times. He also gave lectures in applied geophysics at several other faculties at the universities of Belgrade and Skopje. After the Skopje Earthquake of 1963, Professor Prosen took particular interest in the problems concerned with the reduction of seismic risk. In this field he was able to make an important contribution when other major earthquakes occurred later in Yugoslavia (Banja Luka 1969, Western Slovenia 1976, Montenegro 1979, and Kopaonik 1980). He took an active part in the scientific projects of the Association of Seismological Institutions of the S.F.R. of Yugoslavia. This Association awarded him in 1985, posthumously, The Andrija Mohorovicic Medal, the highest Yugoslavian award for achievements in the field of geophysics and seismology. For many years Professor Prosen was an active member of a number of international scientific bodies. From 1970 onwards, within the framework of the European Seismological Commission he headed the Working Group for the Eastern European Region of the Subcommission on Deep Seismic Sounding. He was chairman of the Committee for Geophysics of the Carpatho-Balkanic Geological Association, and a member of the Geodynamics Project for the Alpine-Himalayan region. He was also a member of a number of national committees and societies for geophysics, engineering geology, and hydrogeology. Professor Dragutin Prosen will be remembered as an indefatigable scientist and teacher, and in spite of his achievements a man of much personal modesty.

J. Lapajne, Ljubljana

General activity report of the ESC President

"Ladies and Gentlemen, dear colleagues, in my report I will review the activities of our commission since the last General Assembly in Moscow, two years ago. Furthermore, I will touch some problems of our commission in facing in the future.

At first, I want to emphasize once more that we are holding here in Kiel our twentieth General Assembly. The European Seismological Commission has shown and will continue to demonstrate, that it is a lively organization. Quite right in time prior to this meeting, Prof. van Gils, our Secretary General, published the History of the European Seismological Commission. I am thanking the Academy of Sciences of the GDR and the Central Institute for Physics of the Earth at Potsdam for publishing this interesting booklet. Some copies are still available and can be ordered from the Central Institute for Physics of the Earth.

The bureau and the executive committee have been active in the past two years. One meeting took place in connection with the IASPEI General Assembly last year in Tokyo. A second meeting was held at Potsdam in November last year. One of the main topics of these meetings was the organization of this General Assembly in Kiel.

The bureau members and all the participants here want to express their thanks to Prof. Rolf Meissner for the kind invitation and excellent organization of this meeting. This General Assembly shares some meetings and symposia with the European Geophysical Society. The bureau has emphasized at its Potsdam meeting, that contacts to- and cooperation with other geo-scientific organizations, societies and associations are highly welcomed and, that joint meetings should be organized when and where it is appropriate.

The program of the current General Assembly is quite packed and the topics of the symposia are focussed on major scientific problems. (We agreed also, that all country names will be referenced correctly in publications, proceedings and official documents and minutes of this General Assembly.) Recently, some quite new ideas, projects and developments are challenging European seismologists. Some of them I want to mention here:

- Reflection seismology becomes increasingly important for studying the structure of the earth´s crust and uppermost mantle. These studies are to be combined with refraction and wide angle measurements. Results so far obtained yielded astonishing insights into the structure and development of the earth´s lithosphere with far reaching consequences. European countries have started strong efforts in developing deep reflection seismology.

- Continental deep drilling projects give strong impulses for scientific research work as well. I only like to refer to the pioneering results obtained from the Kola deep bore hole. Many new questions have arisen from this direct probing and sampling of the earth´s crust, e.g. questions concerning the nature of seismic discontinuities. The planned continental deep drilling project in the Federal Republic of Germany represents a geophysical, geological and petrological key experiment, too. We can expect that such projects will strongly promote further laboratory and field measurements as well as theoretical studies.

- Seismic hazard assessment has become a priority issue in connection with many industrial activities in modern society such as open coast mining and offshore drilling, siting, construction and management of water reservoirs, nuclear power plants, waste disposals, etc.

- Broad-band digital seismology opens new horizons for studying structure and physics of the earth´s interior as well as of seismic focal processes by using the full frequency spectrum of seismic waves. Digital methods of data acquisition, transmission and processing have revolutionized both seismological research and practice.

- Laboratory investigations including those under high temperature and high pressure conditions play more and more the role of key experiments indispensable for understanding petrophysical and geophysical processes and the state of the material in the earth´s interior. They are crucial for interpreting properly the data of indirect geophysical sounding methods, seismological data especially.

The European Seismological Commission has initiated or is supporting such new ideas and related projects. Among them I like to mention:

- The project "Construction of Seismotectonic Maps" initiated by the Working Group on Seismotectonic Maps. Especially Dr. Pavoni has made an outstanding contribution to launch this project. The guide-lines were published in Tectonophysics last year.

- The project "European Geotraverse" is a key project in the frame of the International Lithosphere Program. The European Seismological Commission is strongly supporting all related activities. A special symposium is devoted to these problems. The results are of crucial importance for better understanding the complicated tectonic structure and development of the earth´s crust and uppermost mantle along this Geotraverse. Prof. St. Mueller and many research groups in Western Europe have strongly promoted this project.

- In the frame of the International Heat Flow Commission, a brother commission to ESC in IASPEI, the project "Geothermal Atlas of Europe" has been initiated. In this project some activities of the project "Comprehensive Mapping of the Lithosphere" are included, as well. Prof. Hurtig, Prof. Hänel and Dr. Cermak have put a lot of efforts in organizing the co-operation among all European countries ion this matter. The European Seismological Commission and especially the sub-commission on Theory and Interpretation is supporting this project.

- The compilation and interpretation of historical seismograms is proceeding well. A special symposium will be held here at Kiel. The conveners of this symposium have done their best to organize this symposium. It is planned to publish the papers in a special volume. Prof. Gutdeutsch has invited to another meeting on this matter in Austria next year. The European Seismological Commission is sponsoring this meeting.

- The project "Data bank of source mechanisms in Europe" will also be discussed here at Kiel by the Subcommission 3.

- The project "Unification of digital recordings" has great importance. The Sub-Commission 2 takes care of this project. The Symposium EDSNET II is dedicated to this issue.

- Two members of Subcommission 8, Drs. V. Schenk and D. Mayer-Rosa, prepared a draft for the project TERESA (Test Regions for Evaluation of Algorithms for Seismic Hazard Assessment in Europe). This project will be sponsored by ESC.

I think that these diverse activities are demonstrating convincingly the capability of the European Seismological Commission successful to initiate, co-ordinate and carry out co-operative scientific research and to keep pace with current needs, trends and developments. Since the Moscow General Assembly the ESC has initiated or sponsored several meetings. Among them are:

- the international symposium on crack-forming processes held at Liblice, Czechoslovakia and
- the international symposium "Physics and geodynamics of deformation processes in earthquake focal regions" held at Potsdam.

Colleagues from overseas, the United States and China participated in both symposia. We think that this is a very important and encouraging development since ESC should be open to scientific exchange and fruitful connections on a wider scale and its achievements and scientific expertises should be attractive also for colleagues from outside of the European region.

Leading seismologists of our commission presented new important results at the General Assembly of IASPEI last year in Tokyo and took the charge of convening some of the IASPEI symposia.

The publishing activity of our commission continued as well. I mentioned already the publication of the History of the European Seismological Commission. I was also informed by our Soviet colleagues that the proceedings of the last General Assembly will be published in the near future. The papers presented at the meetings in Liblice and Potsdam last year will be published by the end of this year or the beginning of next year.

Looking for further activities of the Commission the Bureau and the Executive Committee discussed at their meetings the relation to other scientific societies and international organizations. I mentioned already, that the Bureau highly welcomes joint meetings with other organizations among them the European Geophysical Society, the European Association for Earthquake Engineering, the KAPG, the Carpatho- Balkan Geological Association or others. After the reorganization of the European-Mediterranean Seismological Centre a stable and efficient way of international organization and co-operation with our commission has been found.

The relation to the ORFEUS project will be discussed here at Kiel. The Sub-commission 2 is in charge of this question. On-going as well as planned international programs and projects will have further influence on the research work within our commission. Such programs are: the "International Lithosphere Program", the program "Global Change" and the program "Man and Biosphere". These and other international programs include some aspects typical for the European region. Therefore, our commission should be well aware of respective developments.

Our Sub-commissions have to do their best to initiate, to promote and to bring to bear new ideas and new projects. We know that ESC has no money to run special projects on its own, but none the less ESC should take the initiative to develop out of its many scientific discussions suitable proposals which could be taken up and financed by the appropriate national or international authorities. Furthermore, we must be aware that developing countries are looking at seismologists in the European countries. I think we should increase especially the scientific contacts to the countries from Northern Africa.

Finishing my report, I am convinced, that ESC will continue to play an important role in contributing to the further progress in geosciences. Beside this ESC has a proven capability to add share to mutual understanding, co-operation and peaceful coexistence amongst the peoples of our continent. And this should be our deliberate contribution to keep and strengthening peace in our region."

Miscellaneous

On the occasion of the 35th anniversary of the foundation of ESC and her 98th birthday, a telegram was sent to Miss Inge Lehmann , one of the founders, expressing the best wishes of the ESC.

Joint opening ceremony of EGS - ESC:

After a musical overture, Prof. R. Meissner, Chairman of the Local Organizing Committee welcomed the participants. Greeting addresses by the President of the University of Kiel, the Secretary of State and the President of the City Council were delivered. As honorary speaker followed Prof. E. Seibold, President of the European Science Foundation. Finally Prof. M. Petit, President of the EGS, welcomed the participants.

Address by Prof. H. Stiller, President of the ESC

"Dear colleagues, I am very glad to welcome you at the joint meeting of the European Seismological Commission and the European Geophysical Society. The European Seismology Commission is holding its 20th General Assembly here in Kiel. During the last week three important symposia have been performed, many fruitful scientific discussions have taken place. At the meetings of the subcommissions new ideas were initiated and proposals for further cooperation have been forwarded. The Geophysical Institute of the University of Kiel, the local organizing committee with its chairman Professor Rolf Meissner and the bureau of the European Seismological Commission have done their best to make the twentieth General Assembly of the ESC a success. On behalf of all the participants I like to express my hearty thanks.

The European Seismological Commission as the only regional Commission of the International Association of Seismology and Physics of the Earth´s Interior of the International Union of Geodesy and Geophysics highly welcomes joint meetings and joint symposia with other scientific associations, societies or organizations.

The work of the European Seismological Commission is aimed at fundamental and applied seismological research and related interdisciplinary seismotectonic, geotectonic and geodynamic investigations in Europe. Especially these latter complex tasks require the involvement of a great variety of geophysical and other geoscientific methods and approaches. We welcome, therefore, close relations with the European Geophysical Society, with the Commission of the Academies of Sciences of Socialist Countries for Planetary Geophysical Research (CAPG) but also with the European Association for Earthquake Engineering and with the IAEA (International Atomic Energy Agency, Vienna) and other related non-governmental as well as intergovernmental scientific organizations and bodies. With regard to the EGS there are common interests of both organizations, especially in the field of global and regional tectonics and geodynamics as well as in the development, establishment and co-ordinated use of new generation of seismological equipment and regional networks.

The European Seismological Commission has continued its publishing activities. Many members of the European Geophysical Society may be interested e.g. in the History of the ESC, which was written by the Secretary General of the ESC, J.M. van Gils. The ESC, being 35 years old now, is none the less young in its ideas and flexible in its approaches. This is not a contradiction to the statement in my presidential address last week, that the ESC will continue to feel bound by the two basic ideas of its founding fathers:

- At first our commission has to study European seismological problems. The European region can be understood as unique textbook for seismological and related geoscientific problems. In a relatively small area quite different tectonic and seismogenic units are bordering. The complexity is rather high. There are highly mobile tectonic chains in the Alpine region, consolidated as well as proterozoic platforms and shields. Strong lateral variations of the thermodynamic conditions and the physical properties within the Earth´s crust and upper mantle have been observed and provide us with a key to understanding the tectonic development and seismicity patterns in Europe. Dense population and highly sensitive buildings and industrial facilities add to the challenge for detailed seismological studies.

- The second basic idea has been and continues to be, that our commission is aimed at promoting collaboration and co-operation between seismologists nearly from all European countries, countries which belong to different social and political systems. Most of the European countries are small. International co-operation is indispensable, the more so since tectonically controlled seismic activity and hazard is not confined to national boundaries.

These two basic ideas have been and will continue to be a stable basis for our work. It will both enable us to meet the challenges of the future and provide the necessary activities for cooperation with all scientific organizations which feel obliged to serve the same scientific goals and aspirations. They should, therefore, also be the platform for future joint activities of the ESC and the EGS. In this sense I wish to meetings of our two organizations here in Kiel much success and hope, together with all of you, for many more brilliant scientific contributions and inspiring discussions. Thank you for your attention."

ESC Council meeting on 25. Aug. 86, 18:30 - 19:30

Present are the following titular members and SC chairmen: Aichele (SC2), Alekseev (proxy for USSR), Bonnin (invited, EMSC), Camelbeck (proxy for Belgium), Cara (France), Harjes (proxy for F.R. Germany), Hjelme (Denmark), Israelsson (Iceland), Kulhanek (Sweden), Lapayne (invited for Yugoslavia), Levy (proxy for Bulgaria), Lopez-Arroyo (SC8), Mayer-Rosa (Switzerland, proxy for Norway, Bureau), Mendes-Victor (Portugal), Morelli (Italy, SC6), Oncescu (invited for Romania), Pearce (U.K.), Ritsema Netherlands), Shapira (Israel), Steinhauser (proxy for Austria), Stiller (German D.R., SC5, Bureau), Teisseyre (Poland), Udias (SC3,Bureau), Van Gils (proxy for Luxembourg, Bureau), Vanek (CSSR),

Elections:

The general secretary explains the rules for the election of the bureau for the period 1986-1988. The right to vote is reserved to all titular members (in case of absence the vote can be transferred to a member of the bureau), the members of the bureau, the chairmen of the subcommissions and, according to the valid regulations, the director of European Mediterranean Seismological Centre. One person cannot have more than one vote by reason of his different offices.

The **election of the bureau** for the time period 1986-1988 is carried out in a successive manner. First the president, then the two vice-presidents, the general secretary and the adjoined secretary are elected by secret ballot. Following are the results of the elections: President: C. Morelli (new), Vicepresidents: I. Nersesov (re-elected), P. Burton (new), General Secretary: D. Mayer-Rosa (new), Adjoined Secretary: L. Christoskov (new), Member by right as immediate past president: H. Stiller (new).

As last next point in the agenda, the proposed **modifications of the internal regulations** are discussed. No final decision could be reached. The special committee will present its work 1988 in Sofia.

ESC Closing Plenary on 27. Aug. 86

General Assembly 1988:

Having in hands a letter of the Bulgarian Academy of Sciences with the invitation to hold the next General Assembly 1988 in Sofia, Bulgaria, the ESC-President recommends to accept this invitation. The G.A. in Kiel accepts this invitation by rise of hands. The ESC President expresses his sincere thanks to the Bulgarian Academy of Sciences and to the Bulgarian delegate.

Resolutions:
adopted at the 20.General Assembly of ESC in Kiel, 27. 8. 86.

Resolution 1

Recognizing the value of historical information in studying long term seismicity trends, the General Assembly of ESC, gathered at Kiel in 1986,

recommends the coordination of efforts in searching for data on large historical events, develop methods of evaluation for such data and publish special monographs and the organization of a workshop in Vienna in June 1987, and

adopts the establishment of a "Working Group on Historical Earthquakes" within Subcommission 1 on Seismicity.

Resolution 2

Recognizing the fact, that only monitoring of all possible physical field parameters prior to earthquakes offers a chance for predicting earthquakes, the General Assembly of ESC, gathered at Kiel in 1986, recommends the development and installation of multi-parameter observatories in selected areas in order to conduct the necessary studies.

Resolution 3

Recognizing previous efforts of the Council of Europe in initiating cooperative earthquake research in Western Europe,as has been realized in a similar way by the Academies of Sciences in the other parts of Europe, the General Assembly of ESC, gathered at Kiel in 1986,

appreciates the policy, especially of the "Committee Gestion Coordination (CGC)- Environment and Climatology", to provide funds for the actual implementation of earthquake research leading to better understanding of the physical processes in earthquake prone areas which finally will result in the mitigation of natural hazards, and

takes notice of the offer by the ESC Subcommission on Earthquake Prediction Research to actively cooperate through participation of a representative as observer in forthcoming meetings of the CEC.

Resolution 4

Considering the increasing number of critical structures and facilities exposed to earthquakes, and

recognizing the need for reliable methods to assess seismic hazard in Europe, the General Assembly of ESC, gathered at Kiel in 1986,

recommends the formation of an ad hoc working group "TERESA" within the ESC Subcommission on Engineering Seismology, with the task to compile relevant data and to evaluate existing algorithms for seismic hazard assessment in European test areas, to organize workshops and to publish the results in future ESC-meetings.

ESC-Sponsorships:

- First TERESA workshop on "Seismic hazard evaluation for European test areas" organized by the Geophysical Institute of the Czechosl. Academy of Sciences, Prague (CSSR) in Prague, 26 -30 March 1987.
- Symposium on " Seismicity, Seismotectonics and Engineering Seismology in the Ligurian Area, Italy", organized by the Instituto Geofisico dell Universita di Genova (Italy) in the last week of April 1987.
- Workshop on "Induced Seismicity and Associated Phenomena", organized by the Geophysical Institute of the Czechosl. Academy of Sciences, Prague (CSSR) in Liblice, 14-18 March, 1988
- Workshop on "Seismic waves in laterally inhomogeneous media", organized by the Geophysical Institute of the Czechosl. Academy of Sciences, Prague (CSSR) in Liblice, June 13-18,1988
- International Symposium on "Geodesy and Geophysics of the Earth", organized by the Zentralinstitut für Physik der Erde, Academy of Sciences of the GDR, in Potsdam during 4 days in July/August, 1988.

Closing words by the outgoing President H. Stiller

The outgoing ESC President resumes the activities during the Kiel meeting. Further he reminds the audience, that it is now 35 years, that at the 9th G.A. of the Int. Association of Seismology on 28. August 1951 in Brussels the ESC was founded and incorporated into the IASPEI. The president announces the new bureau and introduces its members. In the following, he wishes the new members of the bureau, president C. Morelli, vice-president P.Burton and general secretary D. Mayer-Rosa much success for the future work.The modification of the ESC regulations is worked out by a special group, chaired by J. Hjelme. It is foreseen, that a final draft can be presented at the next G.A. in Sofia 1988. The president expresses thanks to the sponsoring institutions and especially the local organizers of the Kiel meeting. With very warm and personal words for the outgoing general secretary J.M. "Théo" VanGils, he reminds the audience to the merits of "Théo". He also thanks Prof. A. Udias for his work as Vice-President of the ESC. Finally the efficient organization, accomplished by the ladies-team of the DER-office, is acknowledged.

Words of the outgoing General Secretary J.-M. VanGils

"Mr. President, Ladies and Gentlemen, dear Colleagues: No! I rather want to say: My dear Friends! I received, deeply touched, the kind words of honour, which our President addressed to me. Nevertheless, I am not so sure, that I do really merit them. I always considered the secretariate rather a duty than a burden. More than that, the European Seismological Commission was always very near to my heart. And there are many reasons for this.

First, I experienced the times, when European seismologists started to establish the international exchange of data and to collaborate among each other. I still recall the time, when I entered in 1946 the Royal Observatory in Brussels, and my first task was to acknowledge the receipt of bulletins of the different European countries.

Second, I knew personally all the founders of ESC, such as Inge Lehmann, P. Caloi, J.-P. Rothe, J. Scholte and all the others, and I had the privilege to work with them. I still remember all the hindrances Inge Lehmann had to overcome, until the International Association of Seismology agreed to establish the European Seismological Commission in 1951.

Now, after working 22 years in the ESC secretariate, first as Adjoined Secretary and from 1976 as General Secretary, I have to apologize for my occasionally shown sharpness. In some cases I felt like a tiger with stretched-out claws, to attack those, who tried to hurt the Commission. Today I really feel joy, that my friend Dieter Mayer-Rosa accepted the duties of a Secretary general to ESC, and I hope, that he will continue to fight for our Commission, as I did. The secretariate has always to represent your needs and your ideas. In the past it was always a delightful task for me. I know, that this is very much due to your cooperation. I want to thank you deeply and with great motion for your confidence!"

Transfer of presidency

The outgoing president, Prof. H. Stiller transfers the duties to the new president, Prof. C. Morelli. President C. Morelli points out some of the problems, which have to be handled by the ESC in future. He especially mentions the importance of active involvement of young scientists in the work of the ESC subcommissions and working groups. He sincerely thanks H. Stiller for his successful guidance of the ESC as its president from 1982 to 1986.

ACTIVITIES OF THE ESC- SUBCOMMISSIONS

ESC Subcommission 1: Seismicity

Chairman: V. Karnik, Czechoslovakia
Vice- Chairman: B. Papazachos, Greece
Secretary: Z. Schenkova, Czechoslovakia

SC-1 Working groups and chairmen:

WG Statistical methods; G. Panza
WG Instrumental classification of earthquakes; L. Christoskov
WG Maximum intensity map; C.Radu
WG European earthquake catalogue; V. Karnik
WG Plate tectonics; B. Papazachos
WG Carpathian- Balkan region; V.I.Marza
WG Ibero- Maghrebian region; C. Mendes- Victor
WG Historical earthquake data; R. Gutdeutsch

Activity report 1985-1986:

Organization of the 3. International Symposium on the analysis of seismicity and seismic risk, in Liblice, Czechoslovakia, 17-22 June 1985, sponsored also by IASPEI and KAPG. All papers presented during the symposium were published in two volumes of the proceedings distributed in June/July 1986. The papers reflect very well the trends of seismicity investigations in the European area.

The work on the supplement to the catalogue of the European area (V. Karnik: Seismicity of the European Area, Part I) for 1955-1985 started with the uniform magnitude determination.

The increasing demand for basic seismological information lead to the publication of up-dated national catalogues, e.g. that for Italy (1985, ed. D. Postpischl) and others. This demand is triggering new profound studies of large historical events (see also the project INT/9/066 of the IAEA in which the chairman of the SC is involved). It is desirable to establish a working group on historical earthquakes within the SC Seismicity during the assembly 1986 in Kiel.

The chairman cooperated closely with UNESCO, UNDRO and IAEA in items of the programs of the UN agencies which are related to studies of seismicity. Good cooperation was also established with other SCs of the ESC.

The importance of the services for a rapid epicenter determination, like the EMSC in Strasbourg or ZIPE in Potsdam, for seismicity studies must be emphasized.

Present trends in seismicity studies:

Recent development in seismicity studies is marked by the establishment of numerous telemetered networks monitoring and locating earthquakes from an area of a country or studying local seismicity including micro- earthquakes down to the level of M=1. These investigations are often carried out in connection with siting of critical structures like dams, power plants, deposits of waste, pipelines etc. For the same reason profound studies and evaluation of historical earthquake data are organized to find long term variations of activity and to learn more on the extreme events in a particular earthquake source region. These trends have been also reflected in establishing a "Working Group on Historical Earthquake Data" within the SC Seismicity. It is evident, that the importance of homogeneous earthquake data bases for a sound hazard assessment is growing and all countries members of the ESC are recognizing this fact. It is also why seismicity and hazard assessment studies are supported by the UN agencies, like UNESCO, IAEA and the UN secretariat, i.e. UNDRO, or other organizations (EEC). It is evident, that one of the most outstanding problems in the hazard assessment methodology remains in the reliable estimate of earthquake potential of a particular source region,which can be reduced to the estimate of the largest possible event and of its recurrence period. Various algorithms have been introduced, however, no substantial progress has been achieved because the inputs or the established correlations are still not sufficient.

Proposals for further investigations:

It has been proved that new search and evaluation of historical records is rewarding and new information can be obtained or earlier mistakes can be corrected. Therefore seismologists should seek a close cooperation with historians in searching for earthquake information and in evaluating its reliability. The WG of the SC Seismicity can monitor and review these activities. Another step contributing to the improvement of hazard assessment is a better knowledge of seismicity patterns in space and time. the assumption of stationary of earthquake activity simplifies the reality too much and every effort must be made to discover at least in some regions, the trends in time (time-pattern); the same recommendation can be made as to the space pattern (migration). Theoretical background for treating various patterns exists.

The magnitude- frequency relationship remains as the basis for hazard assessment and its parameters are of utmost importance, particularly M(max). The determination of maximum magnitude can be made only by combining and correlating all possible seismological, geological, geophysical and geodetic information. M(max) assessment should be in the centre of efforts during the coming years, this concerns also other WGs, particularly experts in source physics and seismotectonics. It would be convenient to discuss the above problems and their solution at the next ESC assembly in Sofia 1988, perhaps under the title "Seismicity Patterns and Hazard Assessment". Another occasion for thorough discussion of M(max), seismicity variations and hazard inputs will be during the "4th International Seminar on Seismicity and Risk Assessment",1989 in Liblice, Czechoslovakia. The outputs from both events may serve well for the compilation of a monograph on European seismicity.

V. Karnik

ESC Subcommission 2: Data Acquisition and Interpretation

Chairman: H.Aichele, F.R.Germany
Vice-Chairman: J. Hjelme, Denmark
Secretary: W. Melle, German D.R.

SC-2 Working groups and chairmen:

WG1 Instruments; Ch. Teupser (GDR).
WG2 Standardization and Interpretation; N. Kondorskaya (USSR).
WG3 Data Processing and Collection; M. Cara (France).

Activity Report 1984 - 1986:

At the XIX General Assembly of the ESC in Moscow the subcommission organized a special symposium entitled "Seismogram Analysis and Interpretation of Strong European Earthquakes". The symposium was successful in different respects: The combination of a scientific session with poster session gave the opportunity to demonstrate what the real quality of recorded data is, and what possibilities for a detailed interpretation such data offer. It was suggested to organize similar sessions at future meetings. At the same time it became obvious that more high quality broad band stations with an adequate distribution are needed for seismological research in the future.

At the administrative session of the subcommission it was stated that the structure and the task of the subcommission corresponds with the reorganized IASPEI commission on Practice and that the subcommission should support the activities of this commission within the area of the ESC. It was decided that at the next general assembly a special symposium called "European Digital Seismic Network II" should be organized. In this connection the subcommission can discuss how new developments in seismology can be coordinated in Europe by the ESC.

During the IASPEI meeting in Tokyo the cooperation was continued and it was decided that the EDSNET symposium should be a joint symposium of the IASPEI subcommission on digital seismology and its working group on digital data exchange together with the ESC subcommission 2.

There were no further special activities of the three working groups of the subcommission during the last two years.

During its administrative meeting at the ESC Gen.Ass. in Kiel 1986, the activities of the subcommission 2 within the new developments of seismology in Europe were discussed, as well as the correlation and cooperation with other organizations like the IASPEI commission on practice and its various subcommissions were unanimously confirmed.
H.Aichele

ESC Subcommission 3: Physics of Earthquake Sources

Chairman: A. Udias, Spain
Secretary: E.Buforn, Spain

During its business session in Kiel 1986 several topics were discussed:

The scope of the SC was discussed and the need of emphasizing the role of the SC to coordinate studies on source mechanism in Europe. It was felt, that the organization of the EGS-ESC symposium 20 on "Seismic Source Physics and Earthquake Prediction Research" has rested interest to the scientific session of the SC. It is important, that the symposia do not overlap with the work of the SC, but are held on specific topics. The SC are a vital part of the ESC and its active work is very necessary. The existence of the EGS must question the functioning of the ESC subcommissions.

As an important task of the SC, A. Udias presented the current status of the catalogue of European source mechanisms. This catalogue will include source data (fault plane solutions and other source parameters) determined for European earthquakes with magnitudes over 6. The actual compiled data includes 150 Earthquakes, the majority with more than one solution. Data are now stored in computer form. The form of presentation of data and its graphical display was discussed. It was agreed, that an example must be sent to all interested scientists before the end of the year for suggestions.

E. Buforn from Universidad Complutense, Madrid (Spain) was elected to serve as secretary of the SC.

A.Udias

ESC Subcommission 4: Microseisms and Seismic Noise

Chairman: E.Hjortenberg, Denmark
Vice- Chairman: V.N. Tabulevich, USSR
Secretary: C.Eva, Italy

Activity Report 1984-1986:

The Sub-Commission on Microseisms and Seismic Noise held an administrative and a scientific session at the ESC General Assembly in Moscow on October 4, 1984. The meeting attracted a large audience. The new concepts of evolution equations, active media and seismic emissions were discussed. A report of the meeting has been prepared. In connection with the meeting a workshop on non-linear seismology was held. As a result of the success of the meetings a symposium on microseisms caused by factors internal and external to the earths crust has been adopted for the IASPEI session of the Vancouver Assembly, 1987.

During the years 1984-1986 the collection of research reports and bibliographic references from the members was continued.

At the Nordic Seminar on Detection Seismology 1986 a paper entitled "Analysis and interpretation of NORESS noise records" was presented by Jan

At the Nordic Seminar on Detection Seismology 1986 a paper entitled "Analysis and interpretation of NORESS noise records" was presented by Jan Fyen. Using wave number plots a saw mill was shown to be a strong source for 6 cps microseisms. At the same seminar T. Risbo presented monochromatic lines in IDA data in the frequency range 1-50 mHz. Some lines had a constant frequency others were slowly varying over the 4 months observation period.

At the DWWSSN station Kevo peaks in the power spectra near 25 mHz were found recently by M. Tarvainen.

In Tokyo, 1985, the 6th Report of the IASPEI Commission on Microseisms was distributed (190 p.). It contained the full text of 9 papers presented at the IASPEI Assembly in Hamburg, 1983. Conveners: J. Darbyshire and A.V. Nikolaev.

The seismic noise is a subject of great interest for the Group of Scientific Experts of the Conference of Disarmament in Geneva, because of its influence on detection capability. The short period noise samples collected during the Technical Test in October - December 1984 was the subject of a paper by E. Hjortenberg at the IASPEI meeting in Tokyo 1985. Other results of the noise measurements during Technical Test have been presented as GSE/SG1/6, July 15, 1985 and US/GSE/41, July 1986. These studies illustrate aspects of the world-wide distribution of seismic noise, but the seasonal variation is not covered. A more comprehensive noise description, to be worked out in the future, should include both seasonal and other time scale variations, in addition to variation in frequency and in space.

At the administrative session of the SC in Kiel 1986, the following new members have been accepted: D.Prochaskova,Prague; O. Kulhanek, Uppsala; M. Tarvainen, Helsinki; E. Gordeev, Moscow; the Bureau was re-elected.
Erik Hjortenberg

ESC Subcommission 5: Theory and Interpretation.

Chairman: J. Stiller (GDR)
Vice-Chairman: J. Behrens (Berlin-W.)
Secretary: S. Franck (GDR)

SC-5 Working groups and chairmen:

WG Theory of Seismic Wave Propagation ; V. Cerveny, Czechoslovakia
WG Physics of High Pressures; H. Vollstädt, GDR
WG Complex Interpretation; L. Stegena, Hungary
WG Seismotectonic Processes; N.N.

Activity Report 1984-1986:
During the period between the XIXth and the XXth General Assemblies the activities of the Subcommission members were concentrated on the following topics:

Numerical modelling of seismic wave fields in laterally varying layered structures, including computations of synthetic seismograms, application of tomographic methods, and phenomena of high-frequency radiation of earth quake faulting sources. Such problems have been discussed during the Workshop S-3 at the XIXth General Assembly (Moscow 1984). The cooperation within this field is mainly organized by the mutual exchange of preprints, reprints, progress reports and computer programs.

Problems of seismic modelling have been discussed intensively during the symposium "Physics and Geodynamics of Deformation Processes in Earthquake Focal Regions" organized by the Central Institute for Physics of the Earth (Academy of Sciences of the GDR) and sponsored by ESC and Inter-Union Commission on the Lithosphere WG 9 (Potsdam, November 1985). On example is the investigation of acoustic and electromagnetic emission spectra at fracture. Further activities in this field have been included in the annual series of International Training Courses on Tectonics, Seismology an Seismic Risk Assessment organized by the Central Institute for Physics of the Earth (CIPE) Potsdam and sponsored by UNESCO.

During the XIXth General Assembly of ESC in Moscow 1984 members of our SC-5 have been actively engaged in the special work shop "High Pressure Laboratory Investigations for Seismic Interpretation".

Further scientific activities during the period 1984/86 have been pointed out mainly in the participation and arrangement of symposia and sessions in collaboration with other institutions and associations. There are:

- the X. International High Pressure Conference of AIRAPT, Amsterdam, Netherlands, 1985
- the International CAPG-Conference on physical properties of rocks and minerals under extreme p,-T-conditions, Potsdam/GDR, 1985
- the EHPRG-Meeting in AUSSOIS/France, 1984.

The high pressure laboratories of the WG-3 members (Clausthal-Zellerfeld, Frankfurt/ Main, Karlsruhe, Kiel, Kiev, Moscow, Miskolc, Munich, Potsdam, Prague, Warsaw) have exchanged in results and papers and finished interesting common experiments. Bibliography reports have to be completed by several laboratories for the last two years.

Activities in the field of complex interpretation have been concentrated on stress determinations in the Aegean area and quakes and stresses in the Aegeis. Furthermore, the correlation between geothermics and earthquakes and the velocity structure and geothermics of the Earth´s crust along the European Geotraverse have been investigated in common papers. Results have been presented on the Potsdam conference on "Physics and Geodynamics of Deformation Processes in Earthquake Focal Regions" (1985).

Also in the last period it was not possible to find a chairman for the WG "Seismotectonic Processes" but nevertheless there have been important activities mainly by scientists from Czechoslovakia, Poland, the GDR, FRG, USSR, and Rumania. A highlight in this field was the International Symposium "Physics of Fracturing and Seismic Energy Release" organized by the Geophysical Institute of the Czech. Acad. of Sciences in Liblice/CSSR, 1985.

As an example of results in this field there have been developed sets of seismological, geological and geophysical maps for the eastern part of the West European platform. The area under study includes the territory of the GDR, of SW Poland, and of the Western part of Czechoslovakia.

Future activities:

During the XX. General Assembly of ESC the SC-5 will organize a business meeting and a scientific workshop "Theory and Interpretation of Seismological Observations".

The Geophysical Institute of the Czechoslovakian Academy of Sciences, together with the Charles University at Prague, will organize a Workshop on "Seismic Waves in Laterally Inhomogeneous Media" at the Castle Liblice, Czechoslovakia, June 13.-18., 1988.

Members of our Subcommission will participate actively in the AIRAPT-conference at Kiev/USSR, August 1987, and in the EHPRG-special meeting at Potsdam/GDR, August 1987.

H. Stiller

Report on the meeting of SC 5 in Kiel 1986:

Date: Monday 25. August, 14:00.

From the discussions on the activity reports and the scientific contributions follows:

The laboratory studies under uniaxial and perhaps triaxial pressure should be intensified. It was recommended to study also dilatancy effects.

The anisotropy of rock samples and generally of anisotropy in the crust and upper mantle is of outstanding importance. Both laboratory and field experiments are to be intensified to study anisotropy effects.

The geothermal conditions within the earths crust and upper mantle are playing a key role for understanding the physical properties. It is recommended, That geothermal studies both in the laboratory as well as in a regional scale should be included in the topics of the subcommission.

The working groups and the structure of the SC should be kept.

The chairman, vice chairman and the secretary are re-elected

The activity reports of the WGs are discussed.

Information is given on the AIRAPT- meeting in Potsdam 1987

Scientific contributions:

L. Waniek: Crack processes under uni-axial pressure conditions.

Z. Pros, J.Bartosek, V. Jelinek: Comparison of elastic and magnetic anisotropies metamorph rocks demonstrated on spherical rock samples.

E.Hurtig: The project "Geothermal Atlas of Europe" - implication for complex interpretation of geophysical fields in Europe.

H. Stiller

ESC Subcommission 6: Deep Seismic Sounding

Chairman: C. Morelli, Italy
Vice- Chairman: B. Guterch, Poland
Secretary: C. Prodehl, F.R.G.

Report on SC6 session in Kiel 1986:
Date: 21. August, 10:10
Present: C.Morelli, R. Meissner, L.D.Brown and Th. Wever:
Discussion on Deep Reflection and Refraction Wide Angle Refl. -Technologies and Improvements. Unification of standards.

Round Table "New frontiers in active seismology" (22.Aug.).

Morelli introduced the discussion on the following items, explicating the reasons of the choice:

Deep Reflection (DRS). Results of the latest years are everywhere excellent, but the advancement to the greater depths (lower crust and upper mantle) requests velocities determined by refraction (DSS).

Processing. Need of new software both for DRS and DSS, possibly starting from the same format (standard) for echageship.

DSS. New technologies are needed. R. Meissner, from the results in Germany and L. Brown from those in USA, indicate the present stage of knowledge from the most important results and the ways of improvements, for the first two items. The very long spread used in DRS (30km) produce enormous amount of data for DSS in the first kilometres, that are not processed. DSS employs similar configurations with geophones at each km. The approach of DRS and DSS is a necessity. P. Giese introduced the philosophy for the new generation of MARS equipment prepared by the Institutes of Geophysics of Berlin, Frankfurt and Karlsruhe. The first two specimen were presented by Ing. Paulat of Frankfurt.

J.Makris gave some information on similar instruments built by the Institute of Geophysics in Hamburg. It is very inexpensive and is operation both on land and at sea (OBS).

A poster presented the new Delft Seismic Vibrator, based on magnetic levitation and developed and constructed by the Delft Technical University.

The general discussion was impressive and exhaustive.

Business matters of SC6:

The maintenance of the SC was voted.

No special resolutions have been presented.

The bureau was re-elected.

C. Morelli

SC-6 Summary of Activities 1984-86

Country	Date of Experiments	Project(s)	Region	Contact address
Austria	1984-1986	Vienna Basin and EGT	45-48N / 12-17E	F.Weber (Montan-University Leoben); H.J.Mauritsch (University of Vienna)
F.R.Germany	1982 and 1984	Central Andean Geotraverse	20-24S / 64-70W	P.Giese (Freie Universität Berlin)
	1983 Aug.- Sep.	Norwegian-Greenland Seas Seismic Experiment	70-75N /10-20W	K.Hinz (Bundesamt für Geowissenschaften und Rohstoffe, Hannover)
	1984 April	DEKORP program, profil 2, Southern part	48-49N / 10-11E	R.Meissner, B.Milkereit, R.Bittner (University of Kiel)
	1984 August	Black Zollern Forest	47-48N / 08-10E	D.Gajewski and C. Prodehl (University of Karlsruhe)
	1984 Feb.-Mar.	Crustal Structure off Morocco coast	31-34N / 09-17W	W.Weigel, V.Gebhardt (University of Hamburg)
	1984 June - July	EUGENO-S: EGT: Northern segment-Southern part	54-60N / 09-16E	E.R.Flüh (University ofKiel), H.Hirschleber (Univ. of Hamburg)
	1984 May	DEKORP program, profile 2 South	50-51N / 08-10E	B.Baier (University of Frankfurt)
	1984 May.	Crustal Structure of Jordan	29-33N / 34-38E	Z.El-Isa (University of Jordan, Amman); J.Mechie (University of Karlsruhe);J.Makris (University of Hamburg)
	1984 Sep.-Oct.; Oct.-Dec.1985	Seismic Studies of potential KTB location Black Forest	48-49N / 08-09E	E.Lüschen (University of Karlsruhe)
	1984 September	Deep structure Jan Mayen Ridge	69-71N / 05-09W	W.Weigel, V.Gebhardt (University of Hamburg)
	1985 August	DECORP program, profile 4	49-51N / 11-13E	H.Gebrande (University of München); R.Bittner (University of Kiel)

Detailed report was delivered in Kiel 1986

SC-6 Summary of Activities 1984-86

Country	Date of Experiments	Project(s)	Region	Contact address
F.R.Germany	1985 August.	KRISP 85 (Kenyan Rift System)	2S- 3N / 36-37E	C.Prodehl (University of Karlruhe)
	1985 June- Sep.	DEKORP program, profile 4 and 4Q	49-51N / 11-13E	G.Dohr (Preussag, Hannover); H.J.Dürbaum (Bundasamt für Geowissenschaften und Rohstoffe, Hannover
Finland	1982 July - Aug.	EGT: BALTIC profile	60-65N / 25-30E	H.Korhonen, U.Luosto (University of Helsinki)
	1985 August	EGT: POLAR profile	67-70N / 23-30E	H.Korhonen, U.Luosto, VM. Ilmola, P.Heikkinen (University of Helsinki)
Ireland	1985 July-Aug.	Celtic Onshore-Offshore Lithospheric Experiment	49-56N / 05-14W	A.W.B. Jacob (DIAS, Dublin)
Italy	1984 August	EGT: Southern Segment, Sicily	36-38N / 12-16E	C.Morelli, R. Nicolich (University of Trieste)
	1985 June-July	EGT: Southern Segment, Sardinia-Tunisia	35-40N / 08-11E	C.Morelli , R.Nicolich (University of Trieste)
Norway	1985 May	Coast-Fjord Project	60-61N / 03-06E	M.A.Sellevoll (University of Bergen)
Poland	1984 Dec. 84 - Feb.	Antarctic Margin Project	62-68S / 56-70E	A.Guterch (Institute of Geophysics, A.o.S., Warsaw)
	1985 July-Aug.	Svalbbard Platform Project	76-81N / 01-20E	A.Guterch (Institute of Geophysics,A.o.S., Warsaw)
	1985-1986	DSS profiles in Poland	49-62N / 10-24E	A.Guterch, M.Grad, R.Materzok, E.Perchuc, St. Toporkiewicz (Institute of Geophysics Warsaw)
Romania	1984-1986	Romanian Geotraverses	43-48N / 20-28E	I.Cornea (Centre for earth´s physics and Seismology Bucharest)

Detailed report was delivered in Kiel 1986

SC-6 Summary of Activities 1984-86

Country	Date of Experiments	Project(s)	Region	Contact address
Sweden	1984 June-July	EUGENO-S: EGT Northern segment-Southern part	55-60N / 07-17E	C.Lund (University of Uppsala).
	1985 August	EGT- POLAR-profil	67-70N / 23-30E	C.Lund (University of Uppsala)
Switzerland	1985 August	KRISP (Kenyan Rift System)	02S-03N / 36-37E	J.Ansorge (Federal Institute of Technology Zürich)
	1985 July	EGT - Southern segment: Sardinia-Tunisia	35-40N / 08-11E	J.Ansorge (Federal Institute of Technology Zürich)
	1985 March-April	DSS Mexico	15-19N / 94-101W	J.Ansorge (Federal Institute of Technology Zürich)
	1985 Oct.	Expanding Spread Measurements in the Black Forest	47-49N / 07-08E	J.Ansorge (Federal Institute of Technology Zürich)
	1985 Sep.- Oct.	Helvetic Traverses across the Alps (Test)	46-48N / 06-11E	J.Ansorge (Federal Institute of Technology Zürich)
United Kingdom	1981-1986	British Inst. Reflection Profiling Synd.	50-60N / 10W-05E	D.H.Mathews (Cambridge University), B.Biggs (GECO),
	1985 August	KRISP 85 (Kenyan Rift System)	02S-03N / 36-37E	M.A.Khan (University of Leicester)
	1985 June-July	EGT-Southern segment	37-39N / 09-10E	P.Barton (Bullard Labs. Cambridge)
Yugoslavia	1985 March - April 1986	Dynamic of earth´s crust and upper mantle	40-45N / 15-23E	T.Dragasevic (RO Naftagas Belgrade)

Detailed report was delivered in Kiel 1986

ESC Subcommission 7: Earthquake Prediction Research

Chairman: H. Berckhemer, FRG
Vice-Chairman: A.V. Nikolaev, USSR
Secretary: A. Mete Isikara, Turkey

Activity Report 1984-86:

At its meeting in Moscow 1984 a working group structure within the Subcommission was found desirable to tackle important scientific tasks on earthquake prediction research more directly. The following three groups have been proposed:

WGl: Physical and structural properties and processes in the seismic source area before earthquakes (group leaders: B. K. Atkinson (U.K.), T. Chelidze (USSR)

WG2: Field observations and techniques (group leaders: J. Meszcua (Spain), I. Nersesov (USSR)

WG3: Algorithms and models of earthquake prediction (group leaders: G. Purcaru (F.R.G.), A. Prozerov (USSR)

Several conferences related to earthquake prediction research have been organized in European countries by different institutions. Members of the Subcommission and the working groups have taken an active part in the following meetings:

"3rd International Symposium on the Analysis of Seismicity and Seismic Risk", Liblice, CSSR, June 17-22, 1985. Conveners: V. Schenk, Z. Schenkova. Eight papers were dealing with seismic regularities and long term precursors. G. Purcaru arranged an ad hoc getting together of W.G.3.

"International Symposium on Physics of Fracturing and Seismic Energy Release", Liblice, CSSR, October 28 - November l, 1985. Convener: J. Kozak. Among the sixty reports presented some twenty papers were dealing with experimental and theoretical research on the physics of the rupture process and changes in material properties prior to the earthquake.

"Symposium on Physics and Geodynamics of Deformation Processes in Earthquake Focal Regions", Potsdam DDR, November 4-9, 1985. Convener: F.Knoll. One of the major topics of this symposium was the stress accumulation and concentration in the seismic source area.

"2nd International Seminar on Earthquake Prognostics", Berlin Free University, June 24-27, 1986. Convener: A. Vogel. Although this meeting was mainly oriented to seismic hazard and risk problems, some ten papers were dealing with source physics and earthquake precursors.

"Summer School on Seismic Hazard in Mediterranean Region", Strasbourg, July 21 - August l, 1986. This summer school was well attended by some 150 seismologists from all over the world. Basic topics on source physics, seismotectonics, regional seismicity were included in the programme.

Earthquake prediction research within the European Community initiated in 1979 by the Council of Europe has found a new organizational structure which may facilitate the execution of actual research projects. An "Ad Hoc Working

Group on Earthquake Prediction" has been established within the "Committee Gestion Coordination (CGC) - Environment and Climatology" with the following goals:

1. Establishment of a research team network with emphasis on a system of portable stations for measurements in high seismic areas and capability of intervening rapidly after a destructive earthquake.

2. Establishing a network of data banks of seismological, earthquake damaging and strong motion data.

3. Related education and training.

The first official meeting took place on June 25, 1986 at Brussels with chairman L.A.Mendes Victor.

The numerous and quite remarkable national and bilateral research activities in European countries are documented in the national activity reports on earthquake prediction research submitted to and available by the Subcommission.

Session of SC7 in Kiel 1986:
Date: 22. and 23. Aug.
Participants: Berckhemer, Isikara, Mendes Victor, Scarpa, Hurtig, Purcaru, Meissner and about 50 guests.

The chairman informed on the "Ad-hoc Working Group on Earthquake Research" established by the "Committee Gestion Coordination (CGC)- Environment and Climatology which held its first meeting at Brussels on June 25, 1986. L.A.Mendes-Victor gave additional information. It was agreed, that a representative of SC7 should be invited as an observer to future meetings (Resolution 2).

The chairman emphasized the need for simultaneous observation of as many as possible physical field parameters in test areas for earthquake prediction research. He proposed a scheme for a multi-parameter observatory , which was discussed by the audience in detail. It was agreed to prepare a draft on the outcome of this discussion.

After an introduction by the chairman the discussion concentrated on the fact, that precursors are observed irregular and sometimes at rather large distances. Some results from laboratory experiment seem to favour these observations. The further discussion lead to the proposal of a model, in which the brittle crust consists of a block mosaic of a certain block size distribution. Major input came from Berckhemer, Gusev, Levy, Purcaru. Purcaru also discussed problems of probabilistic models. The need of combining field observations with laboratory experiments and theoretical models was strongly emphasized.

A report on two cases of earthquake prediction (August 24, 1984 and January 25, 1985) in Israel was given by A. Shapira. G. Purcaru briefly reported on the probability of the occurrence of earthquake based on precursor leading times and on seismic cycles.

The chairman mentioned difficulties to get the working groups established in 1984 operational. The scientific aims for the working groups written down in the minutes of the Moscow meeting are still considered valid. Gusev and Levy expressed the intention to cooperate in modelling of the seismic source region. Hurtig invited the working groups to the "2. Symposium on Physics and Geodynamics of deformation processes in earthquake focal regions" at Potsdam in 1988.

Three resolutions were proposed and accepted by the audience.

1. Taking into account the previous efforts of the Council of Europe and for initiating cooperative earthquake research in Europe, SC 7 expresses its appreciation for the CGC policy to provide now funds for the actual implementation of earthquake research directed towards a better understanding of the physical processes in earthquake prone areas and to natural hazards mitigation. SC 7 offers its active cooperation by the participation of a representative as an observer in forthcoming meeting.

2. Recognizing the fact that only monitoring of as many as possible physical field parameters prior to earthquakes offers a reasonable chance for predicting earthquake, SC 7 recommends the development and the installation multi-parameter observatories in selected test areas.

3. Recognizing the importance of tectonic stress field for understanding the processes in earthquake focal regions, any efforts to implement reliable determination of the in situ stress field are therefore highly welcomed by the SC 7.

Business matters:

The bureau consisting of H.Berckhemer, A.V.Nikolaev and A.M.Isikara was re-elected unanimously by the members of the subcommission.

Discussion on multi-parameter earthquake prediction observatories (Summary)

General considerations: precursors are unstable in occurrence and appearance. There are sensitive and less sensitive stations with respect to particular kinds of precursors. The simultaneous collection of data of as many physical parameters as possible was considered essential for progress in earthquake prediction research. Multi-channel data logger are recommended and available. A high signal/noise ratio is needed which can be achieved by improved sensors and partly borehole installation at remote places. Environmental influences like air temperature, atmospheric pressure, rainfall, magnetic field have carefully to be taken into account.

Particular comments and experiences:

Emission of high frequency elastic signals from the stressed source area has only been studied in a few cases (California, China). Frequencies up to some 10 kHz were observed. The phenomenon is well-known from rock bursts in mines. Borehole sensors of highest sensitivity are required. In addition to counting events, time series are desirable for further analysis (Berckhemer, Frankfurt; Will, Bochum).

Volume borehole strainmeters (Sacks-Evertson) have proven to be an extremely powerful tool for monitoring stress redistribution in earthquake regions. Sensitivity: 10-9 in strain for periods of hours to days. (Stefansson, Iceland).

Tilt measurements with borehole tiltmeters (Askania) can be used for

MULTI-PARAMETER EARTHQUAKE PREDICTION OBSERVATORY

Data-Logger

	frequency/period	sensitivity	installation
acoustic emission	0.1 - 10 kHz		borehole
strain	day	10^{-6}	"
tilt	day	0.2 mseca	"
water level	hour	1 cm	"
water temperature	hour	10^{-3}°C	"
radon	hour	0.2 m Curie/ltr	"
magnetostatic field	day	0.1 nT T	
induced magnetic field	min	0.1 nT Hx, Hy, Z	
telluric field	min week	0.1 mV	
electromagnetic field level	1 - 80 MHz	several narrow bands	
ground temperature	hour	0.5°	
surface temperature	hour	1°C	
atmospheric pressure	hour		
rain fall			
time			
repeated geodetic measurements		10^{-6}	benchmarks

Seismograph

		dynamics	
seismic ground motion	short period	100 - 140 bB	3 Komp.

quasistatic tilt but also for monitoring dilatancy by amplitude variations of earth tides. Five tilt meters are presently installed in the Turkish-German test area in the North Anatolian fault zone (Zschau, Kiel).

Coseismic and praeseismic groundwater temperature changes have been observed (in Japan). The required resolution is better than 10^{-3} °C (Zschau, Kiel).

Radon concentration can be measured in soil, ground water and spring water. Because of the large influence of environmental parameters soil gas measurement have to be used with caution. Today mainly inexpensive integrating techniques (track etch method) are used to average out meteorological effects. Ra-concentration in ground water ranges typically from 0.2 - 10 nCi/l. Preseismic anomalies often reach more than 100%. Track etch methods are used mostly but continuous and quasi-continous measuring systems are available but need experience (Friedman, Vienna).

Repeated measurement of the magnetic field (Total intensity) require high resolution proton magnetometers (0.1 nT) and very careful correction for time variations. This may include local variations due to magnetotelluric currents.

3-component magnetic field measurement with time resolution of about 1 min are needed at least at one place in a test area if telluric measurements have to be properly corrected.

Telluric field measurements are used by the VAN-group in Greece routinely for earthquake prediction. Different kinds of electrodes have been tested. Lead and lead chloride electrodes gave satisfactory results for a limited time. Parallel spreads are recommended to recognize anomalies caused by electrode effects. Stations react very different in sensitivity and must be calibrated (Varotsos, Athens). Observations by other scientist demonstrated the need to correct for magnetic induction signals (Couliaris, Uppsala).

Variations of the level of natural electromagnetic fields prior to earthquakes have been observed by Gochberg, Moscow, but also in China (Hsu, Beijing). Precursory phenomena have reported to be observable in a wide frequency spectrum from 10 Hz to 80 MHz. For sufficient signal/noise ratio observations must be made outside of technical frequency bands.

As already pointed our, many physical fields are strongly influenced by meteorological factors. Their quantitative knowledge is essential for proper interpretation of anomalies.

H. Berckhemer

ESC Subcommission 8: Engineering Seismology

Chairman: A. Lopez-Arroyo, Spain
Vice- Chairman: V. Schenk, Czechoslovakia
Secretary: D. Mayer-Rosa, Switzerland

SC-8 Working groups and chairmen :

WG Macroseismic Scales (N. Shebalin, USSR and G. Grünthal, GDR)
WG Near-Field Seismology (V. Schenk, Czechoslovakia)
WG Seismic Risk and Design Criteria (P.Burton, U.K.)
WG Microzonation (N.N.)

Activity Report 1984 - 86:

During the reporting period 1984-1986, the members of SC-8, according to the reports received by the SC chairmen, have been active specially in the fields mentioned below. This list of activities is by no means complete, it merely contains in a generalized form the research fields mentioned in the different reports of the WGs.

Collection of macroseismic data of recent European earthquakes, reinterpretation of existing macroseismic data, construction of maps with maximum observed and maximum expected intensities. (in many European countries)

Recording and collection of strong ground motion during recent European earthquakes, (Bulgaria, Czechoslovakia, GDR, Finland, France, Greece, Italy, Turkey, U.K., USSR, Yugoslavia,)

a) In Turkey a series of accelerograms have been obtained during the East-Anatolian earthquake on 5. May 1986 near Dogansehir (38.1N/ 37.9E, M= 5.8, focal depth 10km). Recorded maximum acceleration of the main shock was 6%g in 25km distance, and 2.5%g in 55km distance. The stations are operated by the Earthquake Research Department, Ankara. A number of digital strong motion instruments have recorded another earthquake on 6. June 1986 (M=5.7) in the same area. (R.Ates, Ankara)

b) The Institute of Engineering Seismology and Earthquake Engineering, a newly formed organization in Thessaloniki, operates since 1982 a strong motion network of 50 stations all over Greece. This network has already produced some useful recordings.

c) Continuous digital measurement of ground acceleration, near field measurements from underwater explosions of 200 - 1680kg in the Polar profile. Collection of 30 recordings of explosions and earthquakes at distances of 70-16000km.(P.Teikari, Helsinki)

Organization and creation of strong ground motion data banks, which contain not only files of basic earthquake and ground motion parameters, but also files of uncorrected and corrected strong motion records.(Bulgaria, Czechoslovakia, GDR, France, Italy, UK, USSR, Yugoslavia)

Development of new methods of interpretation of strong ground motions

a) Analysis of records in amplitude domain and correlation of quantities obtained from analysis in frequency and time-domain (V. Schenk, Praha)

b) Application of pattern recognition algorithms for classification of strong ground motions according to the macroseismic intensity effects. (Czechoslovakia,USSR)

Seismic hazard and risk assessment of selected areas, big cities and special sites.

a) Testing of sensitivity of results from the viewpoint of seismological- and other geo-scientific data, definition of seismogenic zones and influence of non-isotropic attenuation laws.(USSR, U.K., Switzerland, Greece, Czechoslovakia, GDR)

b) The Geophysical Laboratory, Thessaloniki (Greece) has conducted a number of investigations on seismic hazard assessment and zoning of big cities in Greece, properties of seismic sources and propagation paths of seismic waves, and scaling laws for response spectra.(B.Papazachos, Thessaloniki)

Symposia and Workshops:

Third International Symposium on the analysis of seismicity and seismic risk, 17-22 June 1985 in Liblice, Czechoslovakia. Sponsors were IASPEI, ESC and KAPG. The following topics have been covered: seismicity, seismotectonics, macroseismic investigation, strong ground motion, seismic hazard assessment, seismic risk estimate, microzoning. The proceedings of the Liblice symposium (Editors: V. Schenk and Z. Schenkova, 497pp) will be distributed by the Geophysical Institute of the Czechoslovakian Academy of Sciences, Bocni II, 141 31 Praha 4, Sporilov, CSSR.

12th Regional seminar on earthquake engineering, 12 -25 September 1985 in Halkidiki (Greece), organized by the Earthquake Planning Protection Organization (EPPO) under sponsorship of the European Association of Earthquake Engineering. Topics were : strong ground motion, seismic hazard assessment, earthquake engineering.

Specialist´s meeting on earthquake ground motion and anti-seismic evaluation of nuclear power plants, 24-28 March 1986 in Moscow. Topics were: strong ground motion, seismic hazard assessment for nuclear power plant siting, problems of earthquake resistant design.

TERESA is a European Study Group. Within this project, it is intended to compare methods applied in seismic hazard assessment studies in Europe in selected test areas. It involves the following steps: a) Selection of suitable study-regions, b) Collection of data for each region, c) exchange of data, d) Processing of data using established methods, e) Organization of workshops f) Joint publications. A steering committee will be formed initially with the task to put up the input criteria and to secure financing for each group individually. Several institutions (contact person) have already indicated strong interest to cooperate actively (by Dec. 1986):

Swiss Seismological Service, Zürich (D.Mayer-Rosa)
Geophys. Institute, Acad. of sciences CSSR, Praha (V.Schenk)
Royal Observatory de Belgique, Brussels (T.Camelbeek)
Observatorio Geophysico Sperimentale, Trieste (D.Sleyko)
Z.I. Physik der Erde, Acad. of Sciences DDR, Potsdam (G.Grünthal)

Royal Netherlands Meteorological Institute, DeBilt (I.T.de Crook)
Centro Nationale di Richerche, Milano (G.Zonno)

Other groups are soon expected to join the project.

V. Schenk and D. Mayer-Rosa

Report on SC8 session in Kiel 1986:

Date: 21. August , 15:30

Participants: Lopez-Arroyo, Schenk, Burton, Mayer-Rosa and about 20 guests.

J.M. VanGils opened the scientific session with a description of "Seismicity Studies within the Commission of the European Communities". His presentation was followed by a discussion on problems to establish catalogues and to obtain relevant data.

L.Mendes Victor explained in detail the recent forming of different groups for CEC projects with respect to this topics.

V.Schenk explains the basic philosophy of the TERESA project, a European seismic hazard pilot study, and distributes the initial documents to the audience. The ways of funding for this project are not yet explored. The initiators of this project (Schenk and Mayer-Rosa) will clear this subject also in discussions with the interested parties.

A.A.Gusev presents his paper "Monte-Carlo Simulation of Record Envelope of the Near Earthquake".

Business matters:

It was agreed to propose a resolution on the TERESA project.

The period of office for the bureau is extended to 1988. At that time a new secretary has to be elected. Nominations of candidates are solicited.

D. Mayer-Rosa

Symposia at the ESC-EGS Meeting, Kiel 1986

ESC1: Strong Motion Parameters and Earthquake Hazards, 21.Aug.86
Abstracts in "Terra Cognita" 1986,vol.6,no.3
Papers in ESC proceedings of the XX Gen. Ass. 1986 in Kiel

ESC2: The European Geotraverse, 26.Aug.86
Abstracts in "Terra Cognita" 1986,vol.6,no.3
Papers published in Annalae Geophysicae (Ed. St.Mueller, Zuerich)

ESC3: Historical Seismograms, 22.-23.Aug.86
Abstracts in "Terra Cognita" 1986,vol.6,no.3
Papers published in Gerlands Beiträge zur Geophysik (Ed. E.Hurtig, Potsdam)

S20: Seismic Source Physics and earthquake prediction research, 27.-28.Aug.86
Abstracts in "Terra Cognita" 1986,vol.6,no.3

S21: shear waves and converted waves in applied seismology, 27.Aug.86
Abstracts in "Terra Cognita" 1986,vol.6,no.3

S22: Theory of wave propagation in heterogeneous media, 25.-26.Aug.86
Abstracts in "Terra Cognita" 1986,vol.6,no.3

S23: Seismic Tomography , 28.Aug.86
Abstracts in "Terra Cognita" 1986,vol.6,no.3

S24: European Digital Seismic Network II (EDSNET II), 26.Aug.86
Abstracts in "Terra Cognita" 1986, vol.6, no.3

The EDSNET II Symposium covered three topics: (1) Digital broad-band seismometry, (2) processing and interpretation of broad-band seismograms, array and network data and (3) exchange and transmission of digital data. A digital very-broad-band seismograph was described which records in one digital data stream all seismic signals above ground noise in a frequency band from about 0.1 mHz to 20 Hz.

Contributions on network data processing included algorithms and software packages for frequency sensitive phase picking for local and teleseismic events, interactive graphic analysis for source parameter determination and complex off-line dialogue processes considering networks of independent remote stations as layered computer networks. In a paper on optimum network design for source location in a given hypocenter region the optimization criterion was formulated as a non-linear regression problem which can be solved by iterative methods. In a presentation on microearthquake signals recorded with local digital networks various methods for medium studies were discussed using the inversion of reflection coefficients and the analysis of coda waves. Several contributions reported on the analysis and interpretation of broad-band data from single stations, arrays and networks. For three-component recordings the combination of frequency filtering and polarization analysis provides an effective processing method. Using array or network data, signal analysis can be performed applying the spectral analysis in the frequency-wavenumber domain as well as various stacking techniques in the frequency-time or the wavenumber-time domain.The characteristic multi-pulse form of broad-band seismograms can be explained mainly by complex rupture processes. Source studies reported the estimation of surface wave magnitudes for a distance range of a few tens of km to about 180 degrees as well as the determination of source-time function, focal depth, moment, rupture complexity, radiated energy and stress-drop from teleseismic recordings. The analysis of digital near-field broad-band recordings of an earthquake swarm in Western Bohemia (CSR) should be especially emphasized. A paper on handling and exchange of digital broad-band data stressed the importance of defining standard data formats and software packages for regional and global digital seismic networks.
D.Seidl (F.R.G.) and M.Cara (France)

The European-Mediterranean Seismological Centre, Strasbourg

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Its role:
Locates, on a routine basis, seismic events which occur in the European- Mediterranean area (in a broad sense: from the mid-Atlantic ridge to Iran and from Arctic Ocean to North Africa). Issues monthly a list of hypocenters, within a delay of 2-3 months: locations are given for an average of 110 events per month (80-210). Handles data from more than 750 stations, most of them located in Europe-Mediterranean: nearly all the stations installed in the area report preliminary data to EMSC. An average of 4500 arrival times are used in the computations each month, after selection from a monthly flow of 45 000. Locates potentially damaging earthquakes occurring in the area, through a hurry-up procedure (within 1-2 hours after the occurrence) and makes rapidly informations available to scientists, civil authorities, humanitarian societies, press agencies. Serves as a relay towards international data centres (e.g. ISC, NEIC) for selected data. Makes available to European users GDSN (Global Digital Seismographic Network) "event tapes" received from U.S. Geological Survey.

Its development:
Develops as far as possible automatic procedures (based on a local network of personal computers) to process arrival times collected through commercial data transmission systems. Procedures and know-how could be applied (and/or duplicated) for any other "regional" service elsewhere. Works on inclusion of other parameters in the monthly lists in addition to location parameters (e.g. routine evaluation of focal solution for the strong events, based on reported short-period first motion deviations). Applies new techniques of data compression to seismic signals as an attempt at matching significant seismological informations and transmitting capabilities of data collecting segments to be embarked on near future satellite platforms. Implements an European seismological data bank for storage and easy retrieval of earthquake parameters, and data from which parameters have been estimated. The data base will be accessible on-line from remote request terminals for limited quantities of information to retrieve, and on delayed mode for large amounts of information requested. Has been approached to act as an European centre for dispatching information in case of a strong earthquake for both civil defense needs and to facilitate professional assistance.

Its legal status:
Is a non profit association under French laws. Has members (presently 15) who are institutions (some of them are national agencies) and have votes in the Assembly. They pay an annual fee. Has two "members of right" : the European Seismological Commission and the Institute de Physique du Globe de Strasbourg. Is in close contact with almost all European- Mediterranean seismology institutions/ agencies: They receive the monthly lists of hypocenters against payment of a reduced fee.
J. Bonnin

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UNSTABLE STRUCTURE OF THE CAUCASUS SEISMICITY

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In the present communication seismicity implies a set of parameters describing the entire system of interrelationships between the individual events of some set of earthquakes.

For the most reliable comparison of seismicity and tectonics, one should first reveal the intrinsic structure of the seismic process proper. This operation should be performed irrespective of any use non-seismic data. This explains why the initial data of the present communication are two catalogues of Caucasian earthquakes (see 1 left-hand slide). This is the catalogue of strong earthquakes from historical times to 1982 N = 649, $K \geqslant 12$ ($M \geqslant 4,5$) and The Caucasian Regional Catalogue for 1965-1982. N = 4626, $K \geqslant 9$ ($M \geqslant 3$). From these catalogues the following parameters were only used; 1) time of earthquake, 2) geographical coordinates, 3) energy characteristics.

Slide 2 interprets the two major seismicity parameters used in our study. In our practice we use the parameters activity and fractionality, which are directly related to the parameters a and b from the Guthenberg equations.
Risnichenko and his successors regarded the parameter as stable or nearly stable. Seismicity variations were only considered to be level variations of activity.

To date it has been established that on the average there is a trend for activity correlation and a negative correlation of activity and fractionality.

It has recently been revealed that fractionality is unstable temporaly. In particular, it is suggested by our data on seasonal variations of activity and fractionality parameters (see 1 right-hand slide). The estimates of the parameters on the slide are statistically significant, since the number of events involved in every estimate is 300-600. In addition, for the fractionality parameter, the standard error interval is given. One can see that in the Caucasus, the highest activity is in May, and the lowest in September. Fractionality is highest in August and lowest in June.

Let us consider in this connection, the stability and fractionality parameters the map for activity and fractionality is given in (2 right-hand slide). It is noteworthy that the catalogues CRC and STP only overlap to a small extent. The zones of increased activity in them are practically stable, and γ distributions differ significantly. This may, however, be due to the unrepresentativeness of the observation system for weak earthquakes.

Seasonal variations of A_{10} and γ are only weakly correlated in the counterphase. The temporal patterns of mean regional values are somewhat different (2nd right-hand slide).

The relative stability of activity is disturbed by local peaks corresponding to the strong earthquakes of the region (Daghestan, Chernogorye etc). On the whole fractionality is more variable irrespective of strong earthquakes.

Let us compare now the stability and fractionality patterns in different sub-catalogues (3rd left-hand slide). Here is (4rth right-hand slide) a division into three periods (the borderlines of the periods are the strong earthquakes of 1970 and 1976). One can see that the zones higher activity are static, and the higher fractionality zones are variable, the main structural axes remaining.

And here you see a subdivision into 6 equal subcatalogues (right-Hand 5,6). One can see the same pattern here: the Higher activity zones manifest themselves sporadically, the distribution of γ varies strongly and only the main structural axes remain.

To sum up the above data on variations in activity and fractionality.

Some other approaches are needed (see 3rd left-hand slide) Toru Ouchi and Tomomi Uekava have called our attention to the fact that the Morishita index used in biological studies can be applied for a general evaluation of the pattern of the earthquake set. The method is explained in the left-hand slide and our results in the right-hand slide. Graphs for different catalogues and sub-catalogues are given.

The Caucasian seismicity is neither uniform, nor random in space; it is an essetially clusterised system.

The character of its clustering, whether linear or isometric, cannot be discriminated by use of Morishita index.

For investigating linear clustering, a simple technique of panel evaluation was used - other techniques, too, are possible in principle (8th left-hand slide).

How convincing are these divisions the system of linear clusters appears to be clear enough. But the fractionality along the 50-km bands and in the inter-cluster zones practically coincide. This is indicative that the above division is somewhat artificial.

For investigating isometric type of clustering we used the well-known technique of cluster isolation.

The system of isometric clusters was obtained by means of a computer algorithm of isolating clusters with randomly set initial sentres and a pre-set discrimination level of clusters. Examples of divisions of the earthquake epicenters in the Caucasus in to isometric clusters are given in the 9th right-hand slide. The pattern strongly depends on the discrimination level of clusters and is somewhat unstable temporally. The meanes for cluster parameters for the entire map provide a rough estimate for the giver pattern. With a gradual in crease of the discrimination level of clusters, two stable levels of isometric clustering 80 and 200 km in size are formed. This pattern is almost independent of the initial system of clusters.

Combined (both linear and isometric) type of clustering is typical of the Caucasus seismicity. This may be considered as an index of relatively young seismogenesis there.

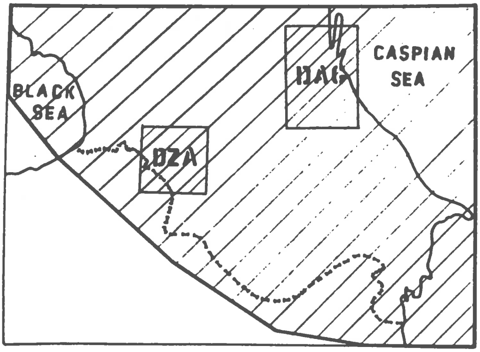
We can declare that young tectonic formations of the Alpine type may tend to isometric clustering of seismicity whereas old zones of post-platform evolution may tent to linear clustering.

INITIAL DATA

1. CATALOGUE OF STONG EARTHQUAKES from historical times to 1982 (STR)
N = 649, K ≥ 12

2. CAUCASIAN REGIONAL CATALOGUE for 1965 - 1982 (CRC)
N = 4626, K ≥ 9

REGION



SUB-REGIONS:

1. DAGHESTAN (DAG), N = 722
2. DZAVAKHETIA (DZA), N = 671

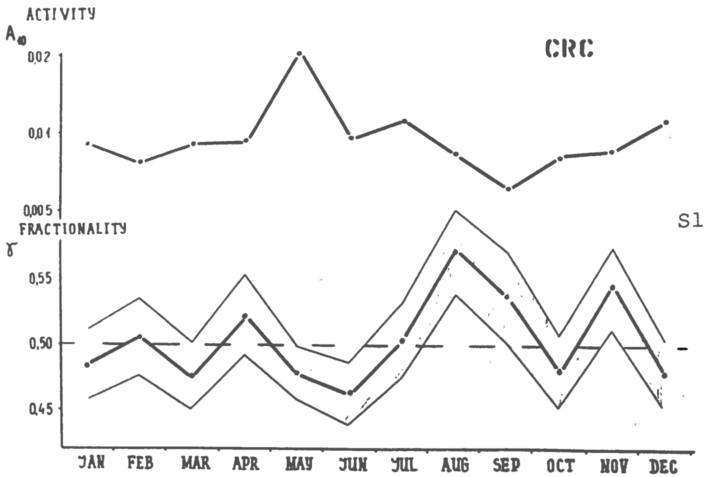
Slide 1 left

SUB-CATALOGUES:

1. 1965 - 1970, N = 978
   1970 - 1976, N = 1714
   1976 - 1982, N = 1934

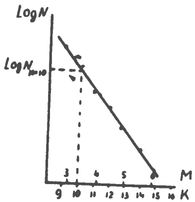
2. 1965, JAN - 1969, MAR, N = 771
   1969, MAR - 1971, JUN, N = 771
   1971, JUN - 1975, APR, N = 771
   1975, APR - 1978, JAN, N = 771
   1978, JAN - 1980, AUG, N = 771
   1980, AUG - 1982, DEC, N = 771

3. RANDOM, N = 1500



Slide 1 right

BASIC SEISMICITY PARAMETERS



SLOPE — FRACTIONALITY

LEVEL — ACTIVITY

Gutenberg: $\log N = a_{M=8} - b(M-8)$

Riznichenko: $\log N = A_{10} - \gamma(K-10)$

if $\log E = K = 1.8M + 4$

slope $\gamma = \frac{b}{1.8}$

level $A_{10} = a_{M=8} + 4.6 b$

γ: maximum likelihood estimation

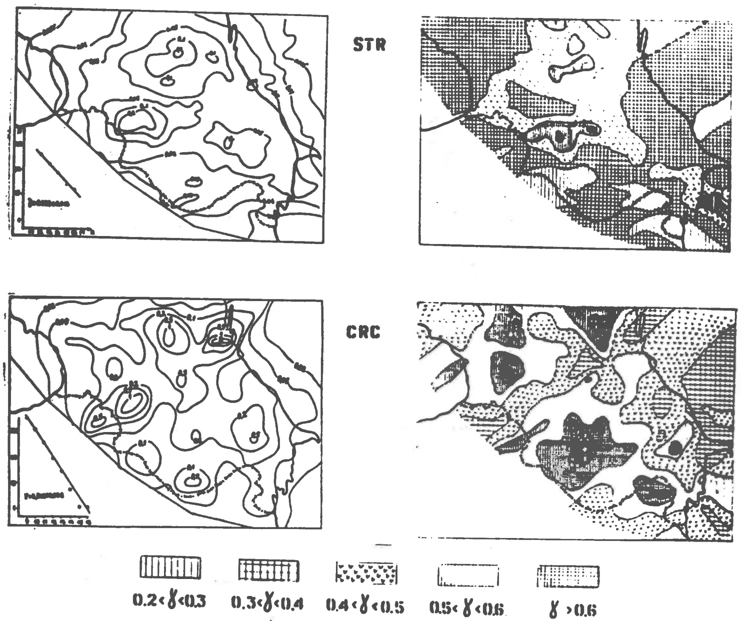
$$\gamma = \frac{1}{\Lambda} \log\left(1 + \frac{N - n_k}{\sum (i-1) n_i}\right)$$

A_{10}:

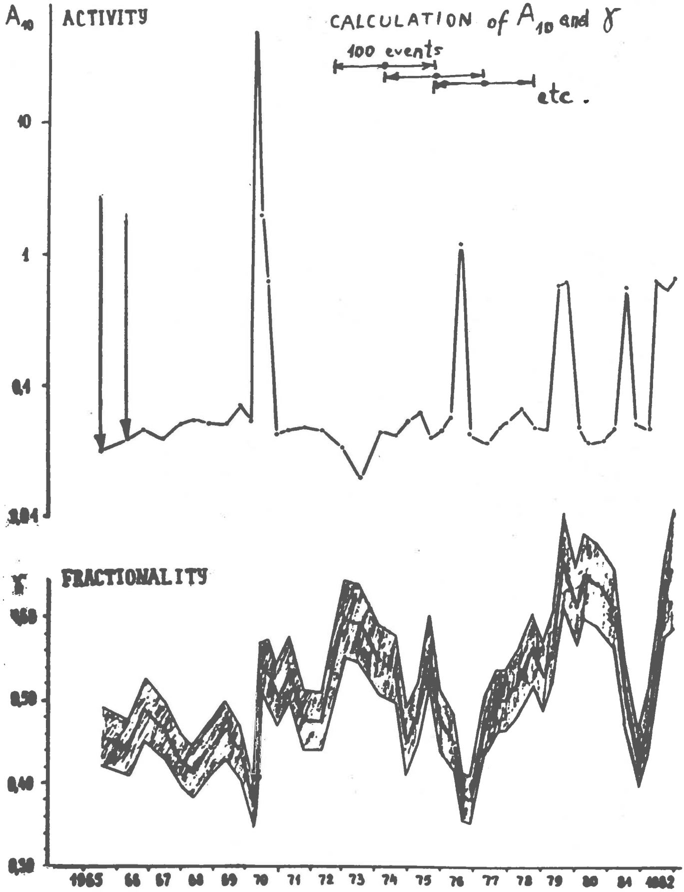
$$A_{10} = \frac{1000}{S \cdot T} \log N_{K=10}$$

Slide 2 left

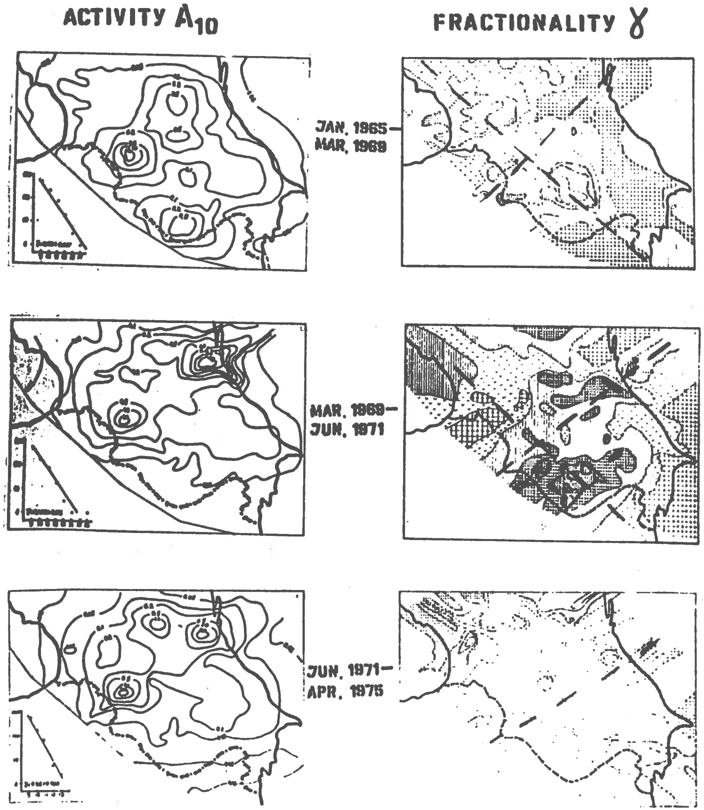
ACTIVITY A_{10} — FRACTIONALITY γ



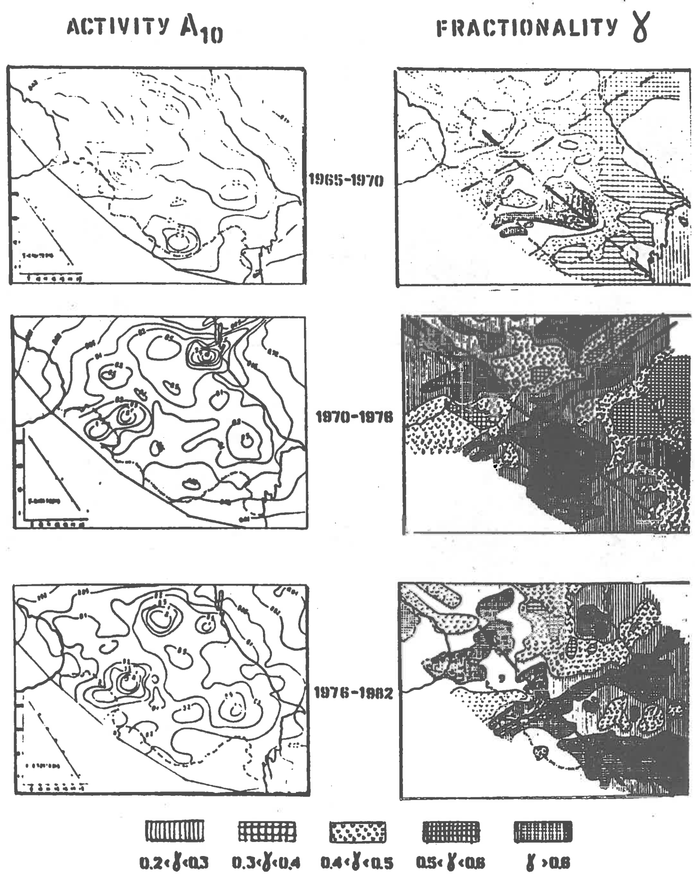
Slide 2 right



Slide 3 right



Slide 4 left

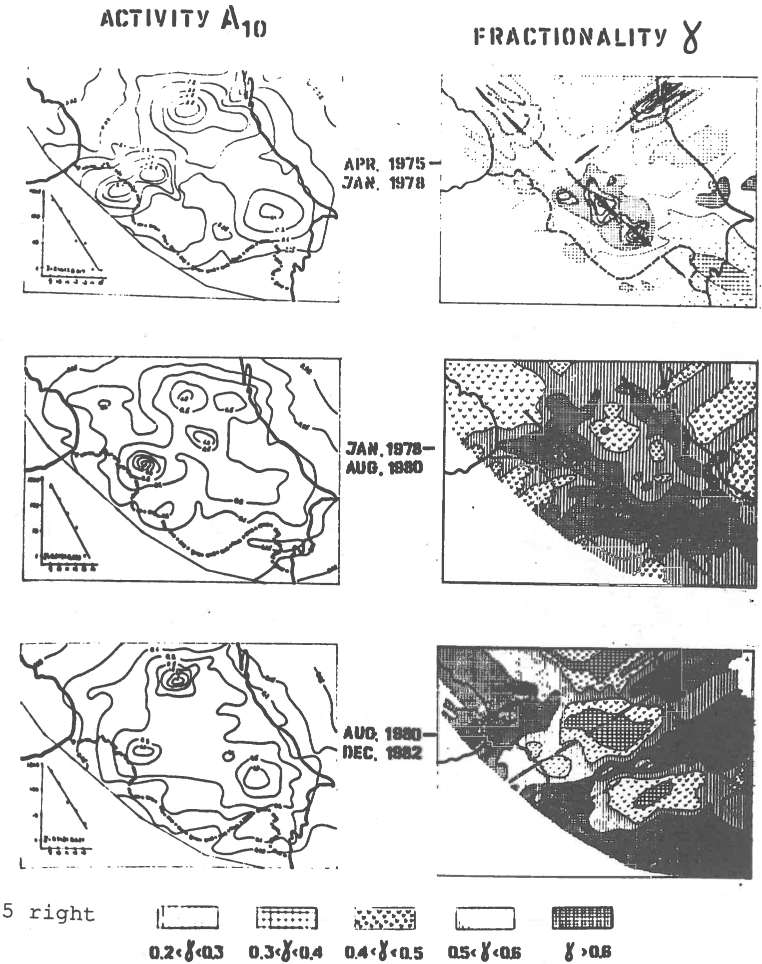


Slide 4 right

General conclustions on the activity and fractionality variations within the Caucasus:

I. Temporal variation of spatial distribution are much better pronounced in the fractionality than in the activity.
2. The prognostic sen●e of fractionality variations is hardly actual there.
3. The maps of activity and fractionality are not sufficient for the complete description of spatial seismicity pattern.

Slide 5 left

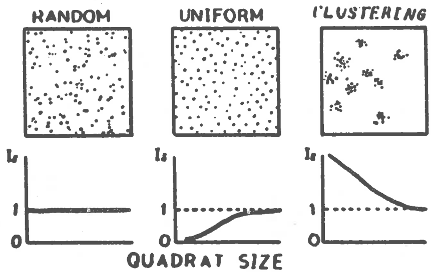


Slide 5 right

MORISHITA INDEX

Toru Ouchi and Tomomi Uekawa

$$I_\delta = q \frac{\sum_{i=1}^{q} n_i (n_i - 1)}{N(N-1)}$$

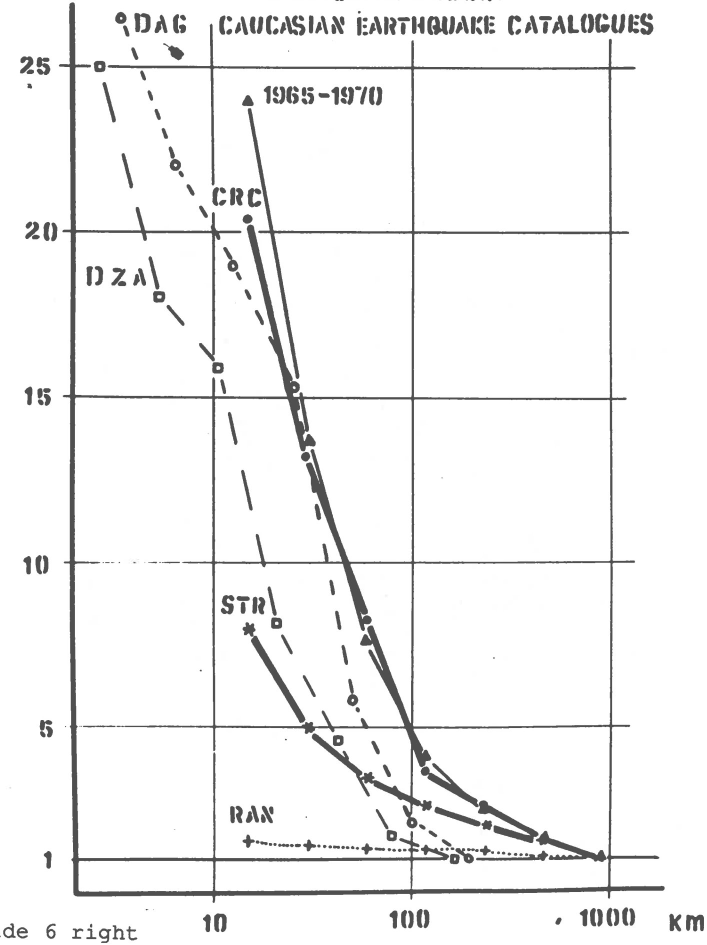


CONCLUSIONS:

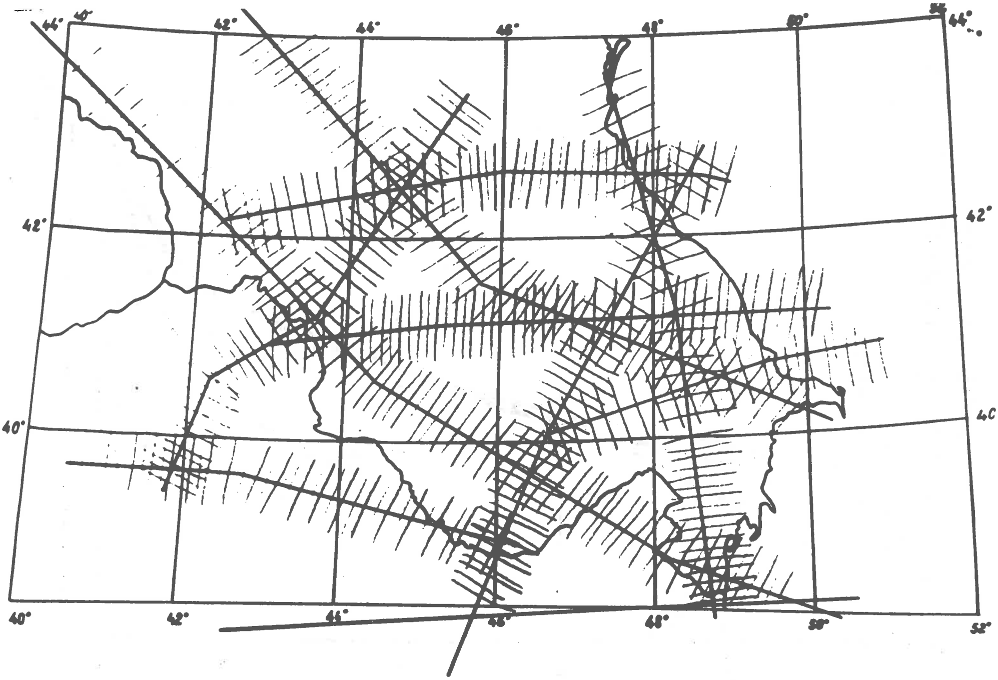
1. The Caucasian seismicity is neither uniform, nor random in space; it is an essentially clusterised system.
2. The character of its clustering, whether linear or isometric, cannot be discriminated by use of Morishita index.

Slide 6 left

MORISHITA INDEX:
CAUCASIAN EARTHQUAKE CATALOGUES



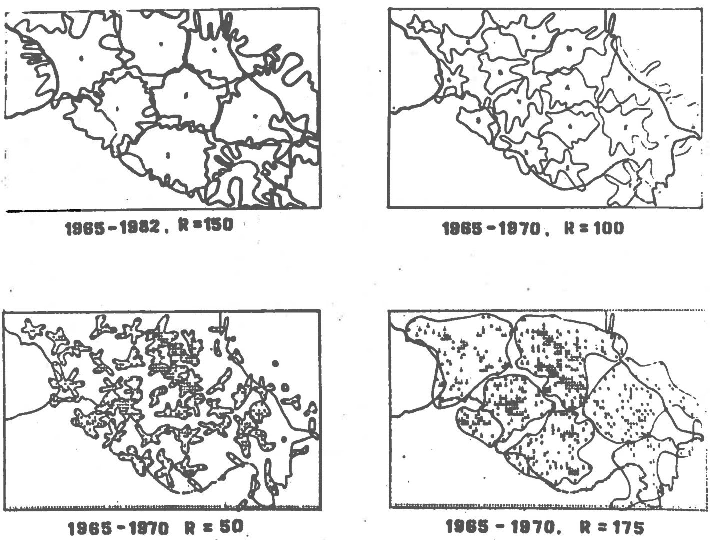
Slide 6 right



LINEAR CLUSTERS: $\bar{\delta} = 0.51$
INTER-CLUSTER ZONES: $\bar{\delta} = 0.49$

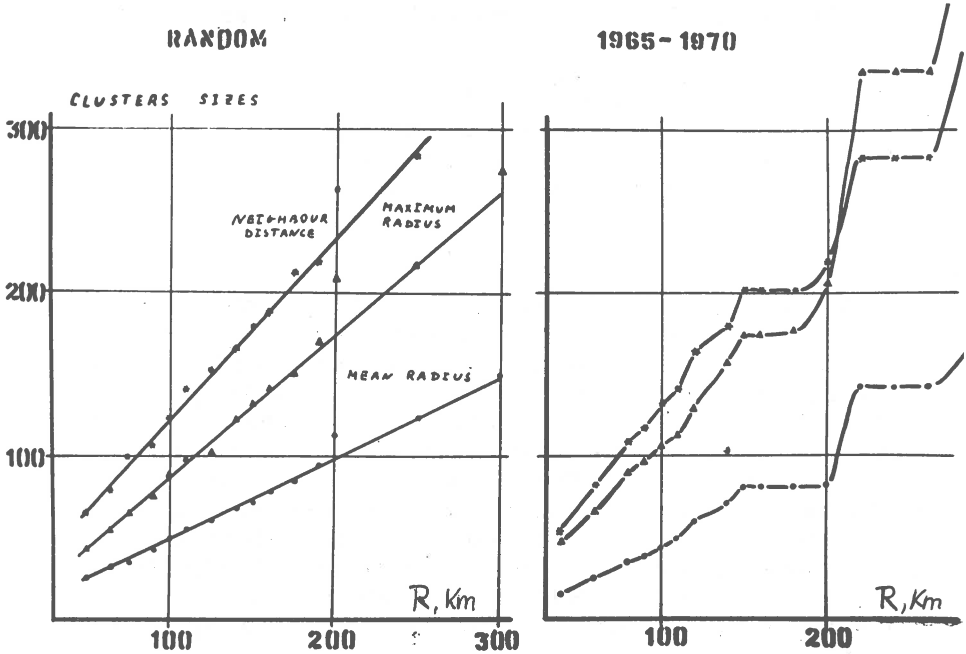
Slide 7 right

CLUSTERS



R-DISCRIMINATION LEVEL OF CLUSTERS

Slide 8 right



Slide 9 right

I. Combined (both linear and isometric) type of clustering is typical of the Caucasus seismicity. This may be considered as an index of relatively young seismogenesis there.

2. We can declare that young tectonic formations of the Alpine type may tend to isometric clustering of seismicity whereas old zones of post-platform evolution may tend to linear clustering.

Slide 10

An Automatic P-Picker for Local and Teleseismic Events

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Abstract
An automatic detection algorithm has been developed which is capable to time P-phases of both local and teleseismic earthquakes but rejects noise bursts and transient events. For each signal trace, the envelope function is calculated and passed through a non-linear amplifier. The resulting signal is then subjected to a statistical analysis to yield arrival time first, motion and a measure of reliability to be placed on the P-arrival pick. An incorporated dynamic threshold lets the algorithm become very sensitive, thus even weak signals are timed precisely. During an extended performance evaluation on a data set comprising 789 P-phases of local events and 1857 P-phases of teleseismic events picked by an analyst, the automatic picker picked 66 per cent of local phases and 90 per cent of teleseismic phases. The accuracy of the automatic picks was "ideal" (i.e. could not be improved by the analyst) for 60 per cent of local events and 63 per cent of teleseismic events.

Introduction
The Swiss seismological service operates an automatic digital data acquisition system which samples 64 channel at 64 Hz on a HP-1000F mini-computer. The FM-telemetered signals are digitized with 10 bit resolution. Event detection is performed by a very simple but fast STA/LTA (short term/long term average) algorithm. An event file is created if at least four out of the 24 vertical component stations trigger within a given time interval.In order to facilitate the analysts work and to calculate a preliminary automatic location as well, a quasi on-line process analyses the event files with respect to dominating frequency and possible P-arrivals.The dominating frequency is determined by the mean frequency of a band pass filter which yields optimum signal noise enhancement. For this purpose, the average signal spectrum is calculated by stacking the smoothed amplitude spectra taken near the STA/LTA trigger time for all triggered stations and the corresponding noise spectrum is obtained accordingly for a time window well before the trigger time. The corner frequencies of the band pass filter is then derived from the ratio of the average signal and noise spectrum. The phase picking is performed on the filtered signals in an other quasi on-line step. The separation of detection and phase picking into on-line and quasi on-line processes results in a considerable computer time reduction on the time-critical parts of the data acquisition process. This, in turn, allows to apply more time consuming and sophisticated algorithms for the post processing of an event.

During a period of eight months the picker algorithm developed by Rex Allen (1978) was implemented on our system to pick precise arrival times. This picker produced very good results for local events because is is primarily sensitive to a frequency increase of the signal. However, for teleseismic events which exhibit a change in amplitude rather than in frequency, it often failed to detect many good P-arrivals. To overcome these deficiencies a new method is presented in the following.

Method:
Phase pickers transform the seismic signal into some time function, the characteristic function (CF), on which the desired phases can be picked. In the case of the Rex Allen picker the CF is

$$CF(t) = y(t)^2 + y\,(t)^2 / K(t) \qquad (1)$$

where K is a weighting factor for the derivative which is proportional to the frequency of the seismic trace. This CF is similar to the envelope function (EF) where

$$e(t)^2 = y(t)^2 + y(t)^2 / w(t)^2 \qquad (2)$$

If the instantaneous frequency w(t) is known, the EF can be calculated. However, this calculation of w is rather time consuming. In order to give equal weights to the amplitude and the derivative, best results were obtained by substituting $w(t)^2$ by $\Sigma(y(t-1)^2) / \Sigma(y(t-1)^2)$ and we may rewrite equation (2) to

$$e(t)^2 = y(t)^2 + y(t)^2 * \Sigma(y(t-1)^2) / \Sigma(y(t-1)^2) \qquad (3)$$

where the sums are taken from the beginning of the record.
As a next step, the EF is squared to $SF= e(t)^4$ where the signal-to-noise behaviour becomes much more distinct. The CF is then calculated by

$$CF(t) = (SF(t) - \overline{SF(t)}) / S(t) \qquad (4)$$

where $\overline{SF}$ is the average of SF and S its variance taken from the beginning of the series to the present time. This definition of CF permits to detect also weak P-arrivals buried in noise which would be lost by the simple STA/LTA criterion used by Rex Allen.
The pick flag is set when CF increases above S1= 10. Sigma (S) is always updated if CF is less than S2= 2*S1 to allow for variation of the noise level.
In order to distinguish between "true" seismic phases and a short term increase of the noise, some additional constraints have to be added:

- A declared event is only accepted as a seismic phase if the duration of the "up-time" (time period during which the pick flag is set) exceeds a certain time period. This time interval can be defined by the corner period of the high pass filter. The minimum duration of an event must therefore amount to at least one full cycle of the longest periods expected. For local earthquakes, where the lowest frequencies of the signal may be rather high, a minimum duration of 0.3 sec is required.
- Due to the complexity of the seismic signals, the CF may not be a smooth function and, furthermore, may drop below the threshold S1 for short time intervals, which would result in premature termination of a phase detection. Therefore, another parameter was introduced, namely the mean of the two corner periods. If the CF drops below the threshold for less than half this duration the pick flag is not cleared.

Results

The use of the above criteria makes the picker equally suitable for both local and teleseismic events. Once the band pass corner frequencies are known there is no need to determine other parameters empirically.

The method described above is illustrated in fig. 1a and 1b for a local and teleseismic event, respectively. The two events were chosen especially to show clear and very weak arrivals as well. For each event, 5 signal traces together with their EF, SF and CF are plotted. A linear scale was chosen for EF and SF in order to visualize the improvement by the use of the non-linear amplification. The dashed vertical line on the signal trace indicates the time where the picker program detected the phase arrival. The CF is clipped at a value of 20, i.e. the value at which sigma is no longer updated.

In fig. 1a, trace 1 is an example of a very clear phase arrival which is never a problem to detect. Trace 2 shows an emerging arrival which was correctly determined, whereas in trace 3 and 4 the pick was slightly late. The CF of trace 3 and 4 rose above the pick threshold at the correct time but was not accepted as a phase arrival because the "up-time" was not sufficient. For the very poor signal-to-noise ratio of trace 5 the picker only detected what turned out to be the S-phase. However, examining the CF for this trace one finds a short increase to the threshold at a time which fits perfectly the P arrival time even though no phase can be seen by eye on the actual seismogram. Therefore, the CF calculated by this method can aid the analyst to read correctly phase arrivals of emergent and weak signals.

Fig. 1b shows seismograms of core phases. For the traces 1 and 2 the picker detected the first arriving P1 phase with a very slight delay. On trace 3, P1 can be seen clearly on the CF, however, its duration was not sufficient for being picked. On the traces 4 and 5 the P1 phase can hardly be seen and the picker, therefore, detected only the P2 phase.

In the following, a situation as in fig. 1b trace 3 will be classified as a mispick, i.e. the analyst timed a phase arrival which differs from the picker by more than 1 sec. If the analyst is not able to read the proper phase as in fig. 1a trace 5 and fig. 1b traces 4 and 5, the pick will be discarded (picker only).

A quantitative analysis of the picker's performance is shown in the left part of fig. 2 for local, regional and teleseismic events. Local events are those within the station network, teleseismic events are at distances of 25 degrees and above, regional events are the ones in between. The number of arrival times picked by both the analyst and the picker are shown, together with the ones read by the analyst only, and the ones which the analyst did not trust and which were discarded (picker only). The picker missed only 3 to 9 per cent of readable phases and but accepted 7 to 25 per cent of phases which had to be discarded. The qualitative comparison of the picker to the analyst is depicted in the right part of fig. 2. The analysts readings were taken as 100 per cent. The number of picks which could not be improved by the analyst reaches 60 to 73 per cent. If picks within ±1 sec are acceptable, the agreement reaches 70 to 85 per cent. The 5 to 9 per cent mispicks are mostly later phases for which the picker failed to detect the first arrival.

Conclusions

The presented method for automatically determining precise arrival times by single trace analysis yields excellent results for local, regional and teleseismic events. This performance was achieved partly due to the choice of the CF (the square of the EF) and partly due to the new trigger criterion with an incorporated dynamic threshold which is sensitive to the variation of the CF rather than its LTA. The automatic picking of first arrival times permits to compute preliminary hypocenter parameters and to alert the seismologist on duty in case of a strong earthquake.

Acknowledgments

I wish to thank Rex V. Allen for making available his picker program to us which laid the foundation for this project. I am also grateful to Erhard Wielandt who wrote part of the filter routines and with whom I had many fruitful discussions.

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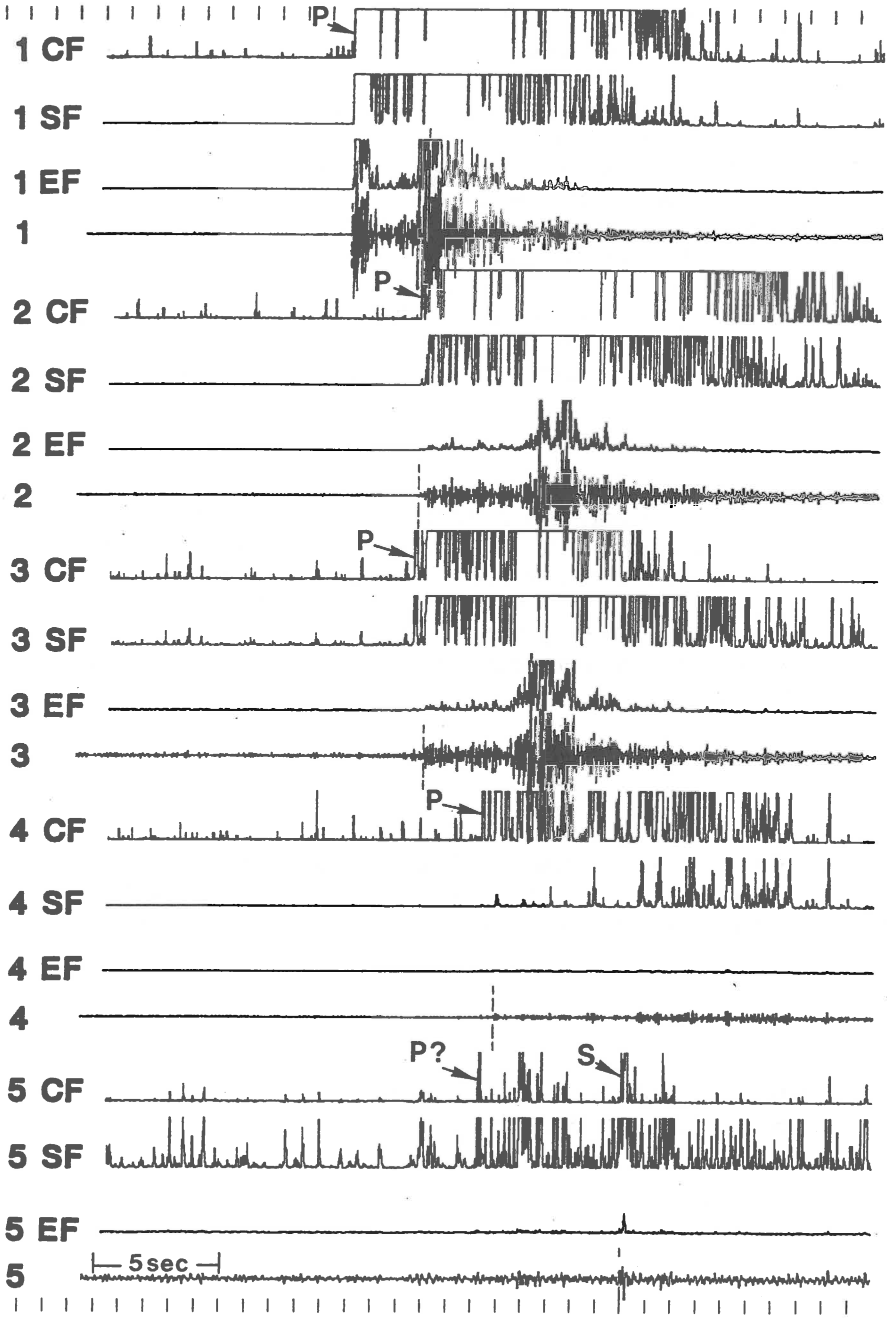

Fig. 1a: Local event EF= envelope function; SF= Squared envelope function; CF= characteristic function. The dashed vertical line on the signal trace indicates the automatic pick. Highpass at 10 Hz, lowpass at 13 Hz.

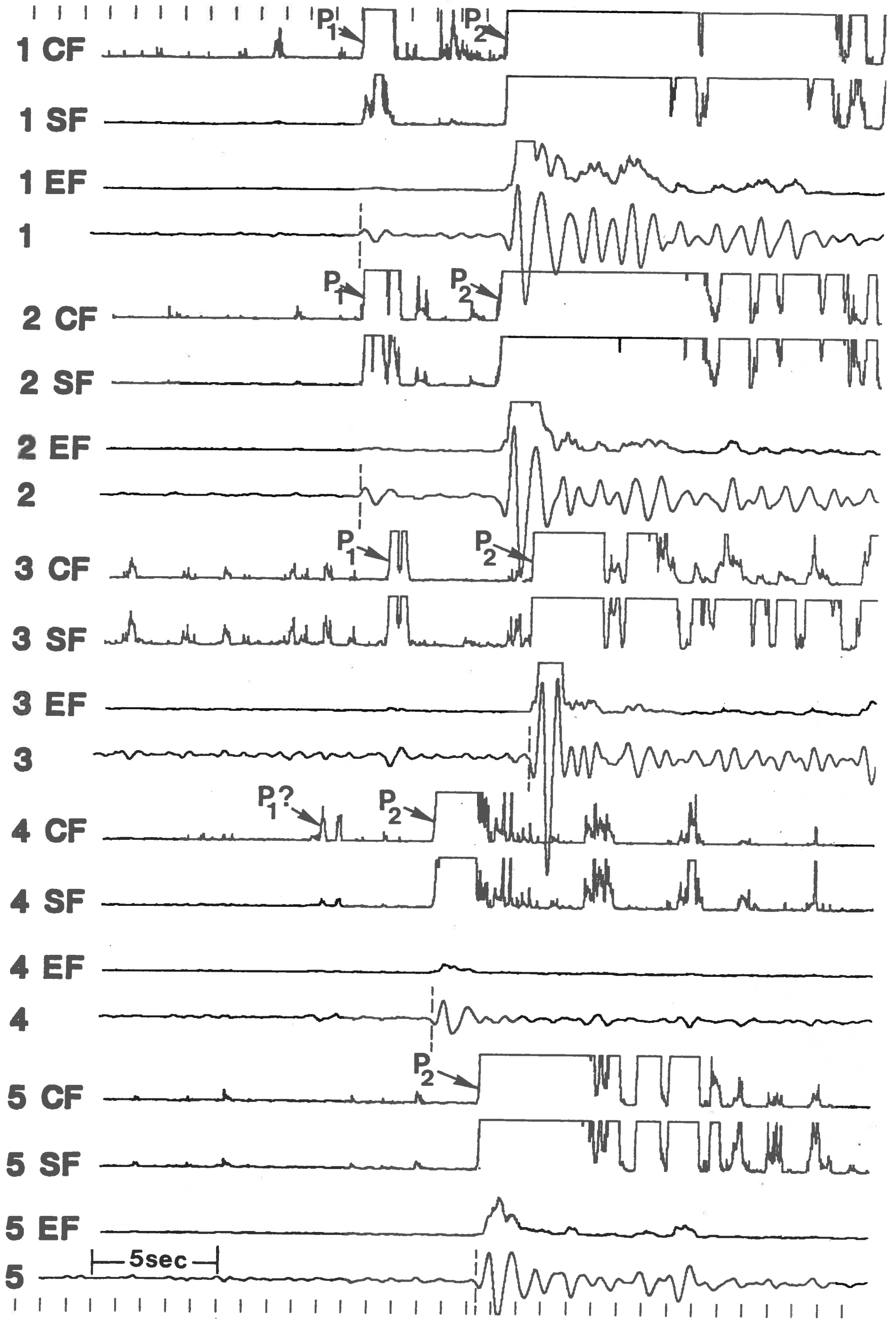

Fig. 1b: Teleseismic event: Highpass at 0.7 Hz, lowpass at 2 Hz (see fig 1a)

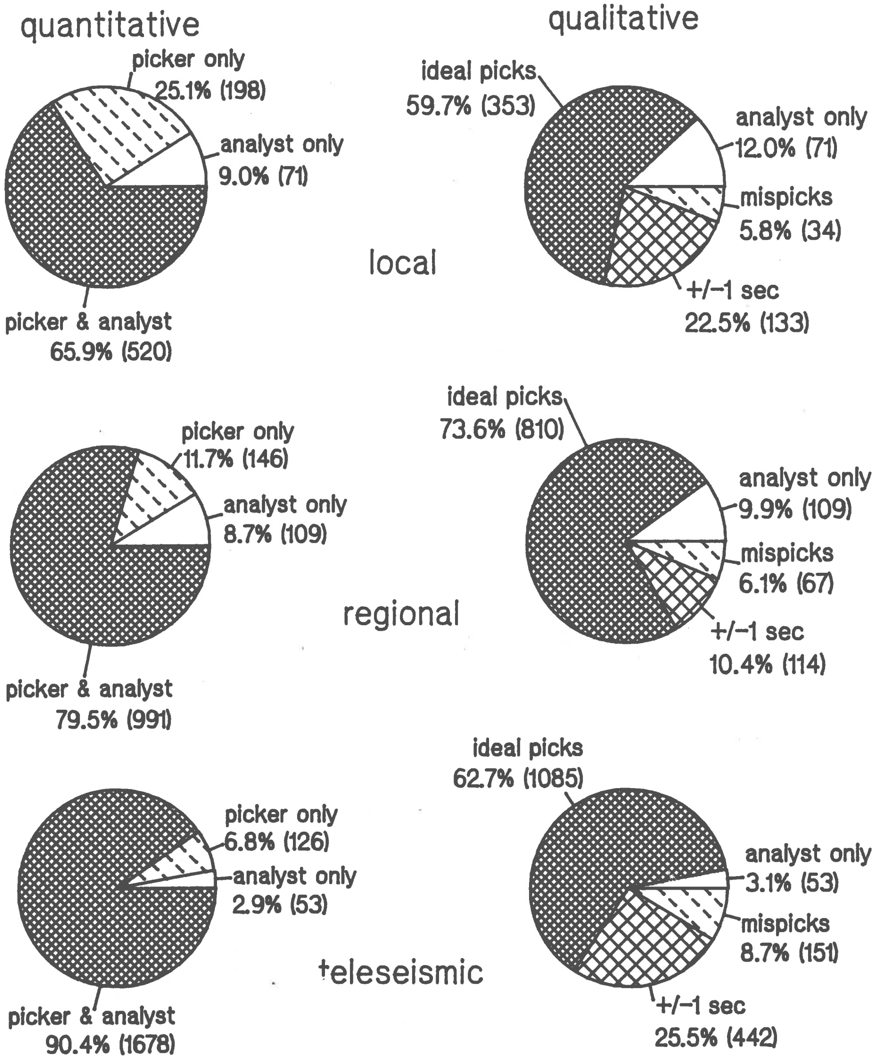

Fig. 2: Performance of the new picker: left quantitative, right qualitative performance.

OPTIMUM PLANNING OF SEISMIC NETWORKS

V.N. Beloborodov, V.K. Gusiakov, O.K. Omelchenko, Novosibirsk, Computing Center, Siberian Division., the USSR Academy of Sciences

The problem of optimum planning of a seismic network is regarded as problem of determination of network configuration for a given number of stations providing the best estimates of hypocenter parameters sought for. Using criteria of "quality of a network" we can find optimum configuration of a network providing the best estimates of the vector of unknown hypocentral parameters. Planning of seismic networks can be made on the basis of several criteria expressing some or other characteristics of the Jacobian matrix J of the nonlinear regression function $\bar{\tau}$ describing dependence of calculated travel times on the distance. In this case the optimum plans depend on the location and configuration of a hypocentral region with the distribution of source parameters over this region described by some function $F(\Theta)$. In this case, we can find the so-called Baies optimum plan

$$\xi^* = \arg\inf \int \Psi(J(\xi, \bar{\Theta}))\, dF(\bar{\Theta}) \qquad (1)$$

where Ψ is the given function dependent on the chosen criterion of the optimum plan, ξ is an element of a set of possible plans. If we cannot predict the fuction $F(\Theta)$ in advance, it is necessary to use the so-called minimax optimum plan

$$\xi^* = \arg\inf \sup \Psi(J(\xi, \bar{\Theta})) \qquad (2)$$

If a set of possible coordinates of stations is restricted, we can find the so-called exact optimal plan by use some iterated procedure of a search for the local extremum of the function Ψ and SVD-decomposition theorem of the regression function $\bar{\tau}$.

FOCAL MECHANISMS OF RECENT EARTHQUAKES IN SOUTH SPAIN

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J. Mezcua, Instituto Geografico Nacional, Madrid, Spain

In south Spain due to the small number of seismological stations and low magnitude of earthquakes there are very few reliable focal mechanism solutions. In the last ten years six earthquakes with magnitude ranging 4.5-5.5 have ocurred in this region, namely, 6 June 1977 (Lorca, Murcia), 20 June 1979 (Granada), 5 March 1981 (Alicante), 24 June 1984 (Granada), 13 September 1984 (Almeria) and 26 May 1985 (Montilla, Cordoba). The increase in the number of seismological stations in recent years and their better distributionallows for the first time to obtain well defined fault plane solutions for these earthquakes. Data show that all solutions have predominant dip-slip motion either reverse or normal which result in small amplitudes for most stations, which difficult graphical solutions. For this reason application of a numerical method provides better solutions and provides the necessary error margins. Mechanisms for the eastern part (Alicante-Almeria) show normal faulting along planes which agree with the general direction of the Alhama de Murcia-Carboneras-Palomeras fault system. Granada earthquakes have also normal faults coinciding with the east-west horizontal tensional character of the depression. The Montilla earthquake, on the contrary, has reverse faulting. These results are interpreted in terms of the seismicity and tectonics of the region.

TEMPORAL VARIATION OF SEISMICITY FOR SMALL EVENTS IN THE MARTIME ALPS (ITALY), WITH REFERENCE TO TIME-VARYING b-VALUES AND RATE OF OCCURRENCE

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The seismic activity recorded in the period 1975-1985 along the northern border of the Mercantour-Argentera Massif has been considered to determine the rate of occurrence and the time-varying b-values. The area appears characterized by a continuous emission of a different seismicity with magnitude less than 4.3. The data set has been analyzed using constant-time or constant-number of events windows; the b-values have been computer with a generalized maximum likelihood method. Long and short period fluctuations of b-values independent of the sampling rate or of the time intervals have been observed. These fluctuations appear more correlated with the rate of energy release than with the rate of occurrence. A more detailed analysis performed before and after the largest shocks shows that generally there is initially a decrease of the b-value and then a return to the mean value.

REAL TIME AND BACKGROUND DATA PROCESSING IN THE BULGARIAN SEISMOLOGICAL NETWORK

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Dimcho Solakov

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1.INTRODUCTION.

Since 1980 the Bulgarian seismological network has been working with telemetrical equipment supplied by Teledyne Geotech (USA) and since 1981 a PDP -11/34 computer has been included for real time and background data processing-[1].

Fig.1 shows the distribution of the stations in the network. Five more stations will be included in near future.

Fig.2 represents the hardware configuration of the digital system,which besides the DEC and Tektronix equipment contains a personal computer "Izot 1031",eight channel analog magtape recorder "Tesla" and eight channel generator for seismic-similar signals.The last two devices used for testing the computer system and some investigations.

The software ivolves the RSX-11/M operating system supplied by DEC and seismological modules by Teledyne.The programs are mainly written in F4P with some modules in Assembler-[2]. Table 1 gives the principle functions of the modules.

Table 1

Module's name	Function
1	2
RTADC	Real time analog to digital convertion of 32 seismological channels.

	1	2
REAL TIME PROGRAMS	SIGTET	Real time detection of seismic signals for every channel using energy-frequaency criterions.
	EVNTDT	Recognizes the seismic events on the base of previously defined number of stations,distance table and travel time function.
	RTHYPO	Performs real time preliminary hypocentral location.
	TAPEWT	Records the signals on magtape.Initiated by EVNTDT.
	SDSPL	Performs 2 minutes disk records of all signals renewed every second.
BACKGROUND PROGRAMS	CAITT	Channel informatin routine.Enters all the parameters of the stations .
	LOCNTL	Hypocentral refinement-coordinates,magnitude,time.
	WFCNTL	Displays the signals,FFT spectral analysis,graph-plotting.
	MERGE	Transfers records between tapes.
	BUCNTL	Produces bulletin of events recorded on tape.
	TBCNTL	Transfers records with events from tape to disks.

2.SOME REAL TIME PROBLEMS AND SOLUTIONS.

The main intention of the system is earthquake location for all the events ,which may trouble the population from any point of the country.

Taking into account the surrounding earthquake regions and the seismicity of our country,follows that the system has to locate events with epicentral distances to the peripheral stations two and more times exceeding the geometrical size of the network.Earthquake location outside the network is a principle problem -[3].

In the same conection is the problem for P and S-wave detection in the availability of high background noise and random seismic-similar noise impulses.Some investigations in the above directions were performed and the results implemented in the system.A short discription of the results follows.

1) Due to the circumstances mentioned above the primary entered program for earthquake location RTHYPO did not give always good solutions. There were examples, with wrong impulses preceding the earthquake, with errors more than hundred kilometres. The reason seemed to be the starting point for the iteration procedure, which was put in the centre of the network. It was not reasonable also to start the iterations from the first station, nor from the point determined by the sequence of the arrivals, again for the little density of the network -[4]. We applied the following method. Let's assign: φ and λ - the geocentrical coordinates of the epicenter; φ_i , λ_i - the same for the i-th station; δt_i - time difference between P -arrival of i-th station and one of the stations recepted as a main station; a, b - parrameters of the travel-time curve linear aproximation; t - travel time to the main station; $x = tg\, at$;

$$y = \frac{\cos\varphi}{\cos at}\ ;\quad z = \frac{\cos\varphi . \sin\lambda}{\cos at}\ ;\quad w = \frac{\sin\varphi . \sin\lambda}{\cos at}$$

It may be shown the following relation is valid:

$$\cos(a.\delta t_i + b) = \sin(a.\delta t_i + b) + \cos\varphi_i . y + \sin\varphi_i . \cos\lambda_i . z + \sin\varphi_i . \sin\lambda_i . w$$

Applying the least-square method for several stations we determine x , y , z and w , thus obtaining better solution for the starting point in HYPO iteration. We consider the improvement in localization is significant.

2) The primary used theoretical relation between P and S arrival times was the following:

$$t_s = 1,7743.t_p + 0,000727.h + 0,0062314.\Delta^\circ$$

where h - is depth, Δ° - the distance. The above equation gives some times more than 3 second error compared with Jeffreys-Bullen travel-time curves. The available memory is not enough to involve the curves directly. That's why the t_s/t_p ratio was included for different distances in the range 0 to 500 km. The result was significant improvement in S -wave detection.

3) The spectral analysis shows significant periodical component in the noise from some stations. A digital prediction error filter was applied to extract and suppress the periodical component. Fig. 3a, b illustrate the increasing of signal to noise ratio in real time and the improvement in P-arrival time determination.

The detail analysis of SIGDET algorithm shows that there is an optimal amplitude threshold, which varys between 1,5 and 3 when the amplitude signal to noise ratio varys from 2 to 5 - [5] . The last result was taken into account when entering the parameters of the system.

5) A digital adaptive prediction error filter was realized to extract P-wave from random noise. The autoregresive coefficients were estimated according to the least-square algorithm given in [6] and using the autocovarianse matrix of the noise by the Burg's method-[7] . Fig. 5 ilustrates the increasing of the signal to noise ratio. The improvement is significant, especioly in low frequansy noise. The program requires more than 20 kB of memory and more that 3 seconds computational time. That's why the real time application wi ll be possible after including additional computer power.

3. BACKGROUND SOFTWARE DEVELOPMENT

The following software modules have been developed and implemented in the system.

- Program package for losses determination during a strong earthquake.

- Modules for seismometer response curve corrections.

- Programs for determination of the main parameters of extended folts.

- Software modules for epicentral location and bulletins for personal computer.

- Modules for least-square method application in geophysical problems.

- A improved modified calibration curve for background magnitude estimation was also include in the system, giving better result with short-period instruments.

4. OUTLOOK FOR FUTURE DEVELOPMENT

There is a plan to extend the system with more powerful computer like VAX11 and 100 mB disk drives. It is planed also to include microporcessors in the stations for preliminary data processing and local use. The system will be equiped with broad band seismometers, especially for some of the stations.

We think there is real possibility to improve the signal detection algorithms and epicentral location. Very usefull in this direction will be possible international real time data exchange.

A significan quantity of hard and software will be implemented in near future in conection with earthquake prediction investigations.

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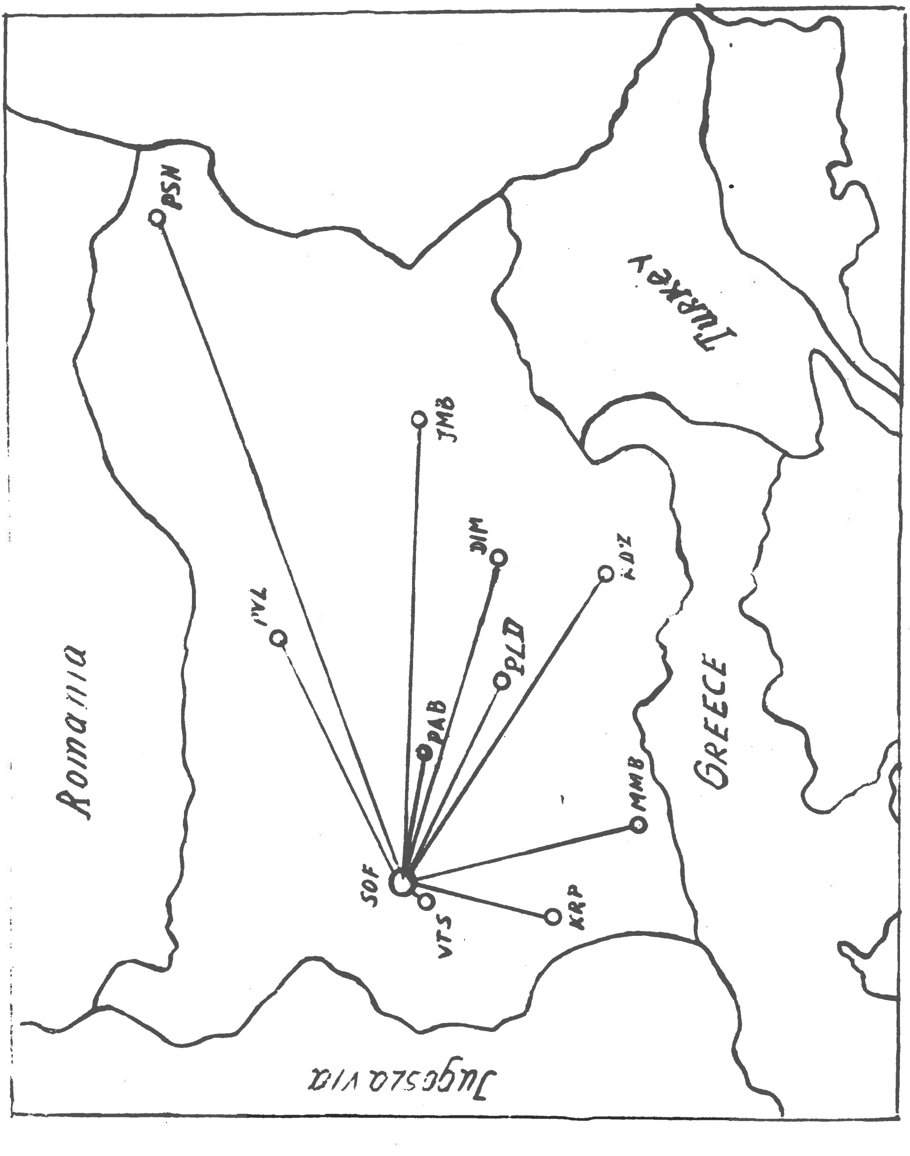

Romania
Jugoslavia
Turkey
GREECE
PSN
IVL
JMB
DIM
KDZ
PLD
PAB
MMB
SOF
VTS
KRP

Fig.1

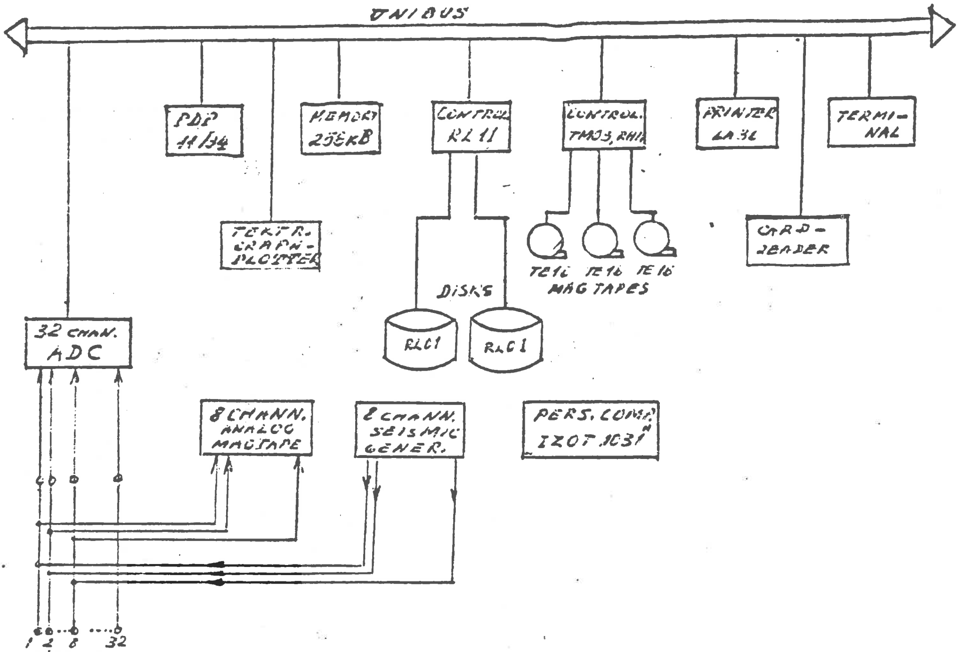


FIG. 2

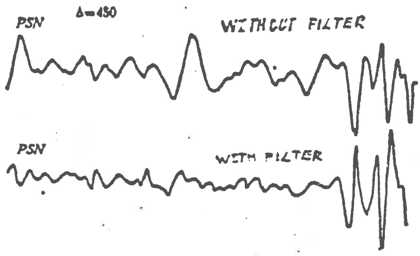


FIG. 4 a

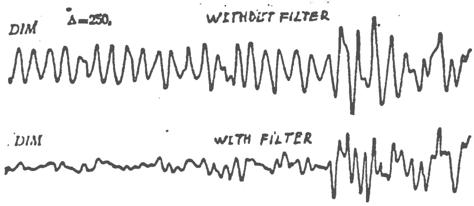
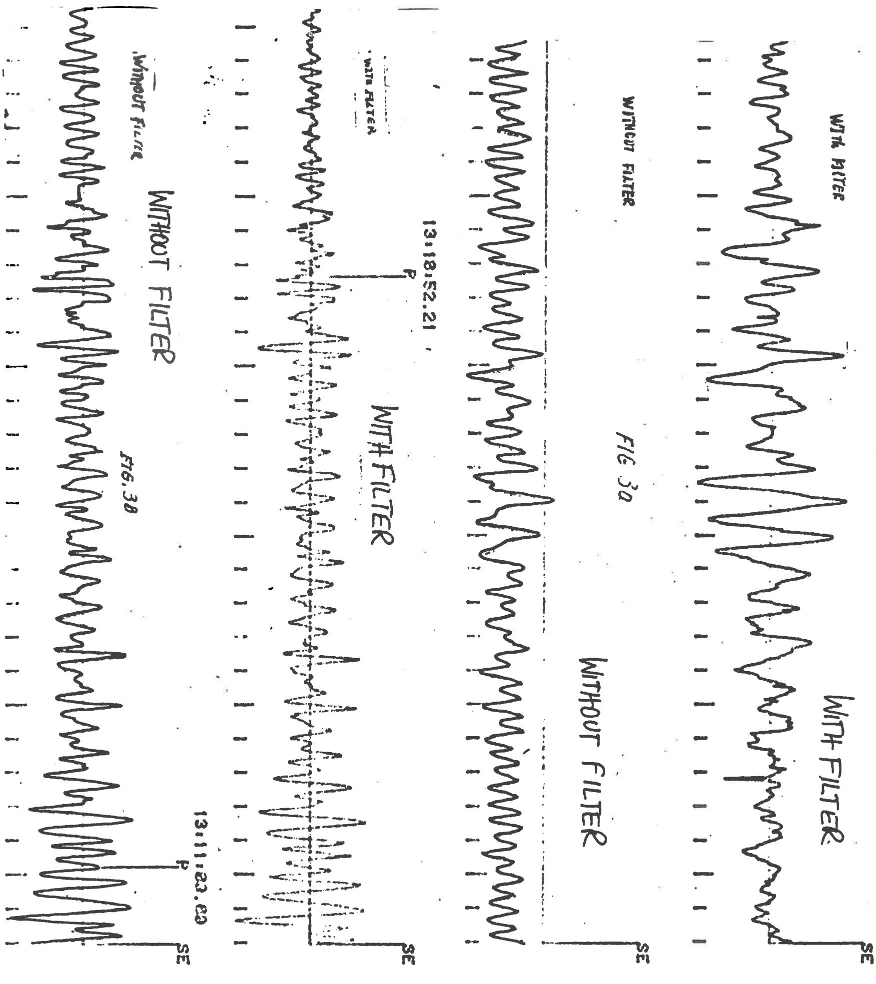


FIG. 4 B


WITH FILTER
WITHOUT FILTER
FIG 3A
WITH FILTER
WITHOUT FILTER
13:18:52.21
P
SE
FIG. 3B

THE REFRACTION OF MICROSEISMS IN NORTHERN EUROPE

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Introduction

It has been stated by S.E. Pirhonen (personal communication) that analysis of signals on the FINSA array has showed that microseismic oscillations in the frequency range .1 to 1 Hz appear to be propagated from the direction of Rockall. This seems at first to be a rather strange result but it could be explicable if allowance is made for the refraction of microseisms over ocean regions due to variation in depth.

A previous paper, Darbyshire and Darbyshire (1957), dealt with the refraction of microseisms with particular reference to the British Isles and showed that the microseismic energy varies a great deal with the direction of approach.

The refraction is caused because the microseisms are modified Rayleigh waves as described by Stoneley (1926), propagating with the same phase over the ocean depth and underlying bed so that the velocity approaches the velocity of sound in water when the depth is large and that of a Rayleigh wave in the ground when the depth is very small. Tables giving the variation of velocity with frequency and depth have been given by several authors and in this paper the values given by Longuet-Higgins (1950) have been used. Figure 1 gives the variation of velocity for 6 second period (1.05 Hz) waves over a range of depths from 100 to 5000 metres. The normal ground velocity for these waves has been assumed to be 2.8 km/sec. This value is somewhat arbitrary but as refraction depends on the relative change of velocities, variations in this value will not be very important.

Method used.

It was decided to obtain the depths from the National Geographical Society map of the North Atl.ntic Ocean. Atlas page 62. June 1968. As this is a Mercator projection, directions from one point to another are correct but distances are not. The map could not thus be used for preparing refraction diagrams without some modification. A compromise was obtained by taking trapeziums with two sides parallel to the latitude parallel and with lengths corresponding to 100 km.,the separation between them also corresponding to 100 km.The map was redrawn so that these trapeziums became squares and were used as a working grid system for computing the ray paths.The X axis was thus taken to be along the E-W direction which remains the same at all points on the map. The normal to this line was taken to be the Y axis but this does not always lie in the N-S direction. As the E-W direction lies closer to the most common direction of approach of the waves, errors due to the limitations of the projection would be minimized. A computer program could then be prepared which worked out the ray paths, the velocities from the tables being stored in the computer memory and the value at any point found by interpolation for its depth from these values.

Results.

The ray paths were worked out for 5,6,7, and 8 seconds period in figures 2,3,4,and 5. They are shown originating from Helsinki (indicated by "H"). By the principle of reversibility, if these lines focus at any point then waves originating at this point would be focussed at Helsinki.The position of Rockall is indicated by "R".Examination of the diagrams shows that there are three direction ranges at Helsinki which give rise to focussing,280-284°N,261-270°N,and 246-256°N.The second of these covers the Rockall area. Microseisms generated from any of these directions would be expected to produce appreciable effects at Helsinki, but the second case does cover an area which is most often traversed by storms moving in a westerly direction and which would be more likely to cause microseisms.

Conclusions.

An investigation of refraction effects, bearing in mind the the most likely location of storm tracks shows that the most frequent bearing of microseisms observed at Helsinki would indeed be near that of Rockall.

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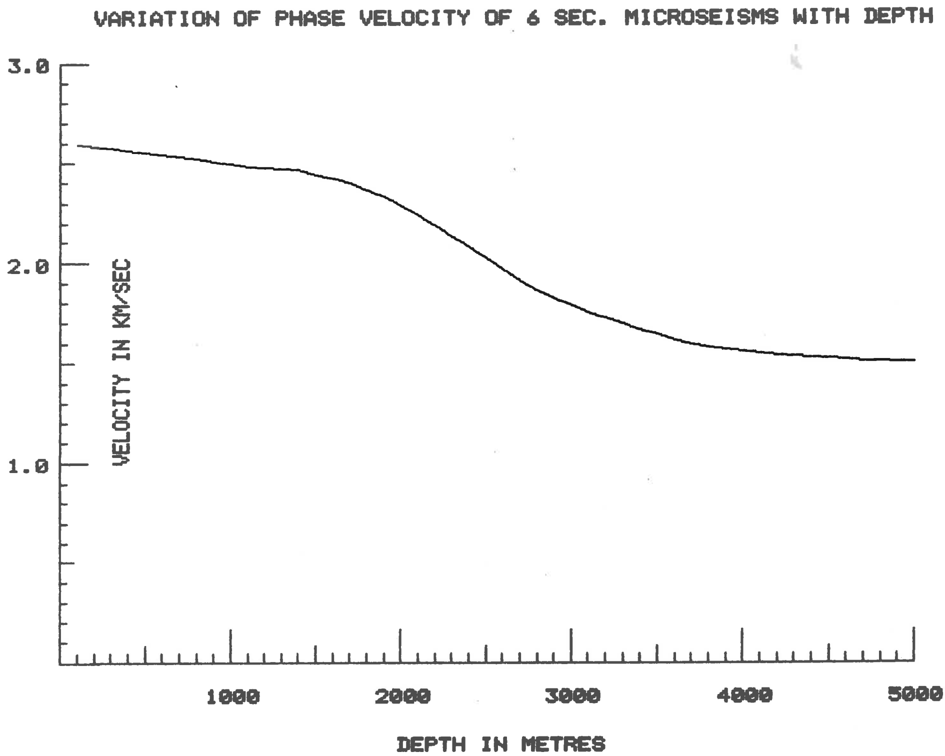
VARIATION OF PHASE VELOCITY OF 6 SEC. MICROSEISMS WITH DEPTH
3.0
2.0
1.0
VELOCITY IN KM/SEC
1000
2000
3000
4000
5000
DEPTH IN METRES

Figure 1

Refraction of 5s. Microseisms

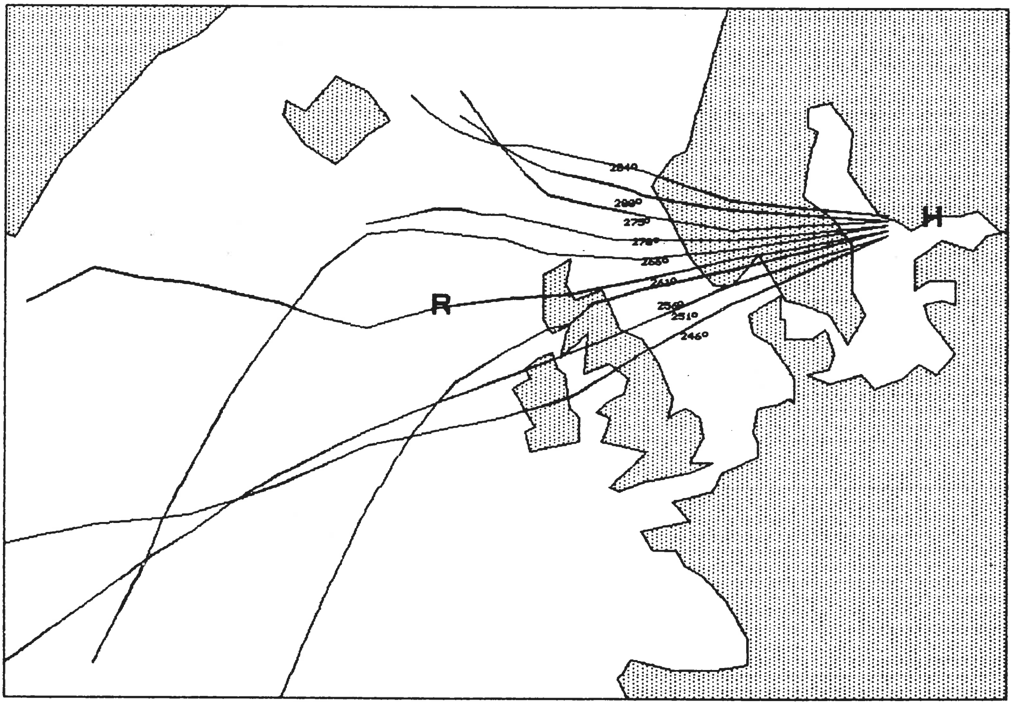

Figure 2

Refraction of 6s. Microseisms

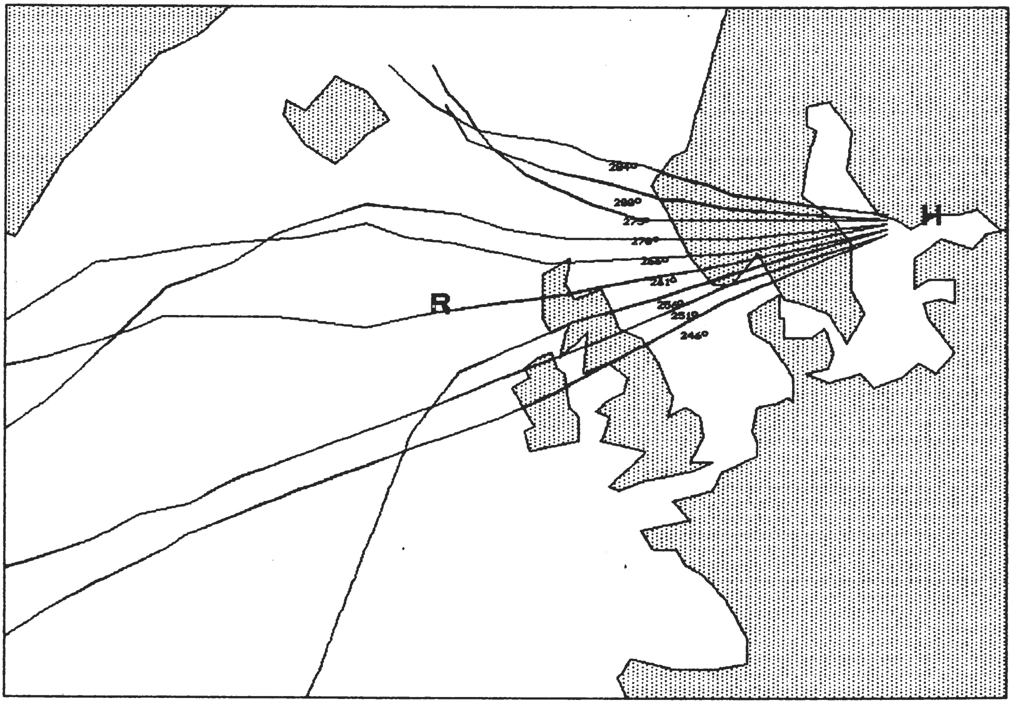

Figure 3

Refraction of 7s. Microseisms

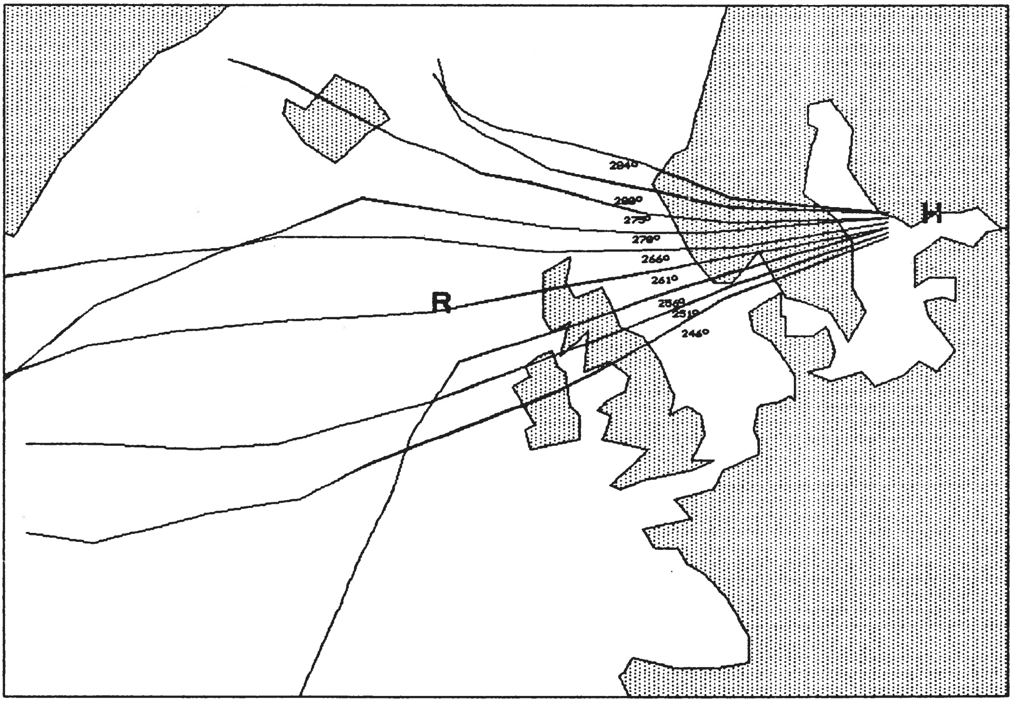

Figure 4

Refraction of 8s. Microseisms

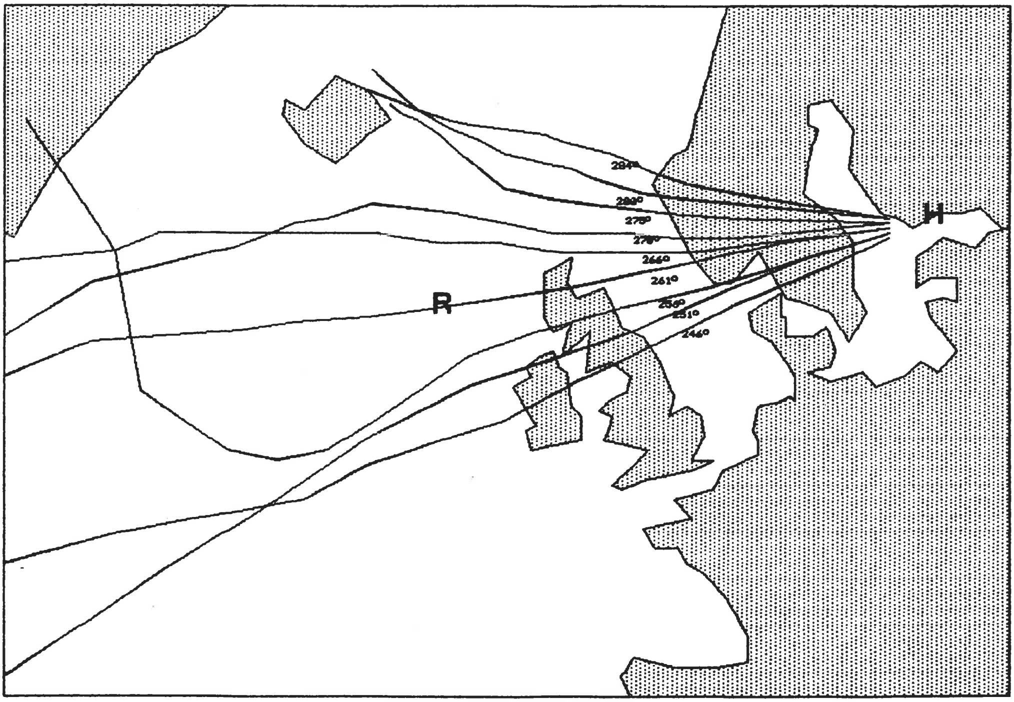

Figure 5

SUMMARY OF RECENT FOCAL DEPTH DETERMINATIONS IN NORTHERN SWITZERLAND

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Based on digital data recorded over the last three years at the Swiss National Seismograph Network and at a new temporary telemetry array, reliable focal depths of earthquakes beneath the Alpine foreland of northern Switzerland could be determined.

The routine location procedure for the earthquakes in this study is based on the widely used computer program HYPO-71 (Lee and Lahr, 1972), using only direct P- and S-arrivals, with a velocity-depth model consisting of a three-layer crust over a mantle half-space. In order to check for possible model-dependent errors, most of the hypocenter determinations were verified with a combination of Wadati and T^2,D^2 methods to obtain values for the origin time and the focal depth which can be considered to be largely model-independent (see e.g. Nicholson and Simpson, 1985). The agreement between the focal depth values obtained by this procedure with those from the routine calculations was usually within 2 or 3 km. In addition, for several of the deeper hypocenters, record-sections were constructed with seismograms recorded at stations along common azimuths; then travel-times of the direct arrivals and of the waves refracted or reflected at the crust-mantle boundary were modelled in a manner similar to that employed in the interpretation of crustal refraction experiments. Since the general trend of the Moho beneath Switzerland is fairly well known from seismic refraction and gravity studies (e.g. Kissling et al., 1983), this procedure constitutes an independent method to constrain focal depths relative to the depth of the Moho, and in fact, served to confirm the existence of the lower crustal earthquakes shown in Fig. 2.

The epicenters of the earthquakes recorded over the three years between 1984 and 1986 in the magnitude range between 0.9 and 4.2, are displayed on the map in Fig. 1. Azimuthal coverage, for several events was improved by using recordings from stations in southern Germany, obtained from the Universities of Karlsruhe and Stuttgart, in addition to those from the stations shown in Fig. 1. As confirmed by locating known quarry blasts and seismic refraction shots, most of the epicenters located within the station network are accurate to ± 1 km. Focal depths with uncertainties less than 5 km are plotted in Fig. 2, projected onto a vertical cross-section roughly parallel to the dip of the Moho. Table 1 lists the relevant parameters used for the HYPO-71 location for all the events included in Fig. 2. Focal depth uncertainties were estimated on the basis of comparisons with the results from the two alternative procedures mentioned above and on the basis of the number of P- and S-readings (NP and NS), the azimuthal distribution of the stations (GAP) and the number of stations with epicentral distances less than twice the focal depth (NZ). The clusters of earthquakes near Winterthur, Hauenstein, Olten and Radolfzell were relocated with a master event technique; this increases the location accuracy of the weak and poorly recorded events in each group to that of the stronger and better recorded ones. For the four weak events near Eglisau, the focal depth could not be calculated but was fixed at 1 km. The shallow focus of these events is deduced from the pronounced surface waves, which suggest that the sources lie in the sedimentary layer, and from the fact that one of them was clearly felt by people living in the vicinity of the calculated epicenter in spite of its small magnitude (M=1.4). The earthquakes in the southern Black Forest and Rhinegraben region (upper left corner of Fig. 1) are not included in Fig. 2, because they lie too far outside of the station array and, consequently, their focal depth determinations are not sufficiently reliable.

The results, displayed in Fig. 2, clearly show that earthquakes in northern Switzerland are not restricted to a particular depth range within the crust, but that they are fairly evenly distributed from close to the surface all the way down to the Moho.

Fault-plane solutions were constructed for all events in the given time period for which a sufficient number of reliable first motions could be determined (Fig. 1). Assuming the rough 45 degree rule for the angle between fault-planes and stress vectors, all focal mechanisms are compatible with the well established general stress field, characterized by a NNW-SSE oriented compression and an ENE-WSW oriented extension (e.g. Pavoni, 1980). The presently available data do not show any systematic change of focal mechanism with depth.

Following the work by Byerlee (1968), by Brace and Kohlstedt (1980) and by others, several authors related the depth distribution of earthquakes in the intraplate continental crust to laboratory measurements of maximum stress values that rocks can sustain (e.g. Sibson, 1982; Meissner and Strehlau, 1982; Chen and Molnar, 1983). Common to all these models is a brittle upper crust, in which deformation is accomplished mainly through friction-failure on preexisting faults, over a ductile lower crust, where deformation occurs by plastic flow. The depth of the brittle-ductile transition is determined by several factors: temperature and pressure, strain rate, mineral composition, water content (pore pressure) and tectonic regime (extension or compression). As mentioned above, this model agrees very well with the evidence from a large number of earthquake studies, as a result of which the great majority of crustal hypocenters were found to be restricted to the upper 15 or, at most, 20 km of the crust. The focal depth distribution of earthquakes beneath northern Switzerland seems to represent a notable exception to this rule (Deichmann, 1987).

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DATE	TIME	LON LAT	M	RMS	NP	NS	NZ	GAP	Z	E	LOCATION
84. 1.11	9:17:35.6	702.4/245.3	1.4	.21	3	5	1	100	10	3	Wetzikon
84. 1.11	14:11:57.8	703.9/243.4	3.2	.11	21	8	1	69	11	2	Wetzikon
84. 4.10	16:50:53.2	609.5/253.3	2.6	.17	14	11	9	75	22	2	Passwang
84. 4.12	0:50:40.5	623.3/253.7	2.5	.16	18	12	11	68	21	2	Hauenstein
84. 4.20	4:34: 4.6	627.6/252.9	1.3	.16	7	11	8	97	14	2	Hauenstein
84. 7.12	8:11:55.1	698.9/281.2	2.0	.05	6	2	0	277	8	4	Diessenhofen
84. 8.26	19:30:45.7	683.3/270.9	1.4	.01	3	0	0	148	1	F	Eglisau
84. 8.31	7:25: .4	695.0/260.3	2.4	.10	14	10	8	131	23	2	Winterthur
84. 8.31	22:44:13.7	695.0/260.5	1.5	.07	4	5	3	132	23	2	Winterthur
84. 9. 5	5:16:49.3	685.0/233.4	4.0	.10	21	5	2	95	15	2	Albis
84. 9.14	22:30:29.4	684.6/232.9	2.9	.13	19	8	9	61	24	2	Albis
84. 9.17	8:48:10.1	634.4/252.6	1.7	.04	6	1	4	167	7	3	Hauenstein
84. 9.17	8:49:50.2	695.1/260.2	2.0	.08	13	8	7	131	23	2	Winterthur
84. 9.19	23:38: 9.9	682.4/270.1	1.2	.11	4	2	0	126	1	F	Eglisau
84.12.23	20:14:59.7	694.4/261.3	1.2	.05	3	3	3	292	22	2	Winterthur
84.12.27	13:45: 6.5	695.0/260.5	1.7	.07	6	5	4	132	23	2	Winterthur
85. 1. 7	9:52:31.5	665.5/223.7	2.1	.09	14	8	11	86	27	2	Hochdorf
85. 2. 3	2:15:38.9	681.5/271.2	1.0	.00	3	0	0	137	1	F	Eglisau
85. 2.24	4:57:55.4	714.5/263.1	1.6	.08	4	3	2	232	14	4	Wil
85. 2.24	21:44:14.7	651.7/251.3	1.6	.06	8	4	8	182	16	2	Schafisheim
85. 3.15	23:31:45.1	683.2/270.0	1.6	.12	4	0	0	126	1	F	Eglisau
85. 5.15	7:45:31.8	634.4/246.5	1.8	.10	5	3	0	271	1	4	Olten
85. 5.16	8:34:45.9	634.2/246.5	1.5	.11	4	3	0	298	1	4	Olten
85. 7. 7	0: 8:57.9	623.8/205.7	2.7	.05	11	3	8	108	30	2	Langnau
85. 9.19	1:57:18.4	626.8/253.2	1.5	.11	13	14	9	96	14	2	Hauenstein
85.11.21	12: 7:44.9	714.3/272.9	2.2	.10	12	9	4	234	25	3	Frauenfeld
86. 2.27	12: 7: 6.8	713.8/282.0	4.2	.08	16	8	2	136	17	2	Steckborn
86. 3.19	23:53:47.8	716.8/260.1	1.8	.16	5	5	1	184	12	3	Wil
86. 3.22	15:37:27.9	623.3/249.0	1.1	.10	7	5	5	282	16	2	Hauenstein
86. 4.10	11:52:13.9	691.4/262.4	2.1	.12	13	7	3	130	13	2	Winterthur
86. 5.30	3:44: 6.8	623.3/252.8	1.8	.10	11	5	7	187	17	2	Hauenstein
86. 6. 5	23:41:46.0	708.1/274.1	2.0	.12	3	4	0	198	9	4	Frauenfeld
86. 6.12	15:24:20.7	624.4/251.8	1.4	.05	6	3	5	275	18	2	Hauenstein
86. 8.31	9:56:24.2	646.7/260.7	.9	.05	7	2	4	136	6	2	Frick
86. 9.17	22: 4:36.5	712.5/288.1	1.4	.09	3	3	0	262	12	3	Radolfzell
86.10. 8	3:12: 7.3	683.4/235.6	2.0	.13	16	9	11	62	28	2	Albis
86.11. 1	4: 1: 8.8	625.1/268.7	1.2	.15	16	6	14	93	17	2	Rheinfelden
86.11. 5	5: 2:51.0	711.2/287.2	2.4	.11	21	11	0	182	12	3	Radolfzell
86.12.12	22:23:19.8	613.4/266.8	1.0	.15	6	4	6	220	12	2	Basel
86.12.12	22:49:29.3	613.4/266.7	1.0	.13	11	8	7	147	12	2	Basel
86.12.13	14:20:51.6	695.2/260.9	2.2	.10	12	10	7	134	22	2	Winterthur

Table 1
Location results for the events included in the depth cross-section as determined with HYPO-71.
LON/LAT = Swiss coordinates (km), (bottom left of Fig. 1 = 600/200);
M = magnitude; RMS = root-mean-square travel-time residuals (s);
NP = number of P-arrivals (weight > 0.5);
NS = number of S-arrivals (weight > 0.25);
NZ = number of stations with epicentral distance < twice the focal depth;
GAP = largest azimuth interval between neighboring stations;
Z = focal depth (km); E = estimated uncertainty of Z (km).

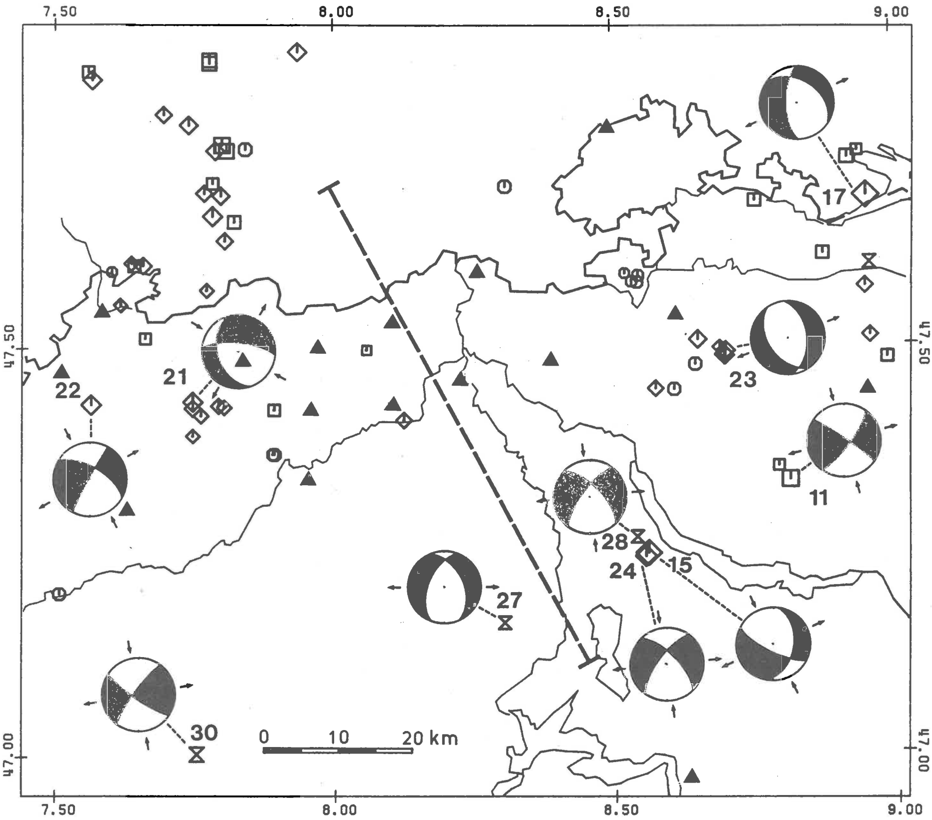

Figure 1: Epicenter map of northern Switzerland for the three-year period from 1984 to 1986, with fault-plane solutions (lower hemisphere equal area projection) and focal depths (km) of selected events. Dark quadrants are compressional and light ones dilatational, whereas arrows indicate horizontal stress directions. The NW-SE trending dashed line indicates the trace of the depth cross-section shown in Fig. 2. Solid triangles indicate seismometer locations. For explanation of the epicenter symbols see Fig. 2.

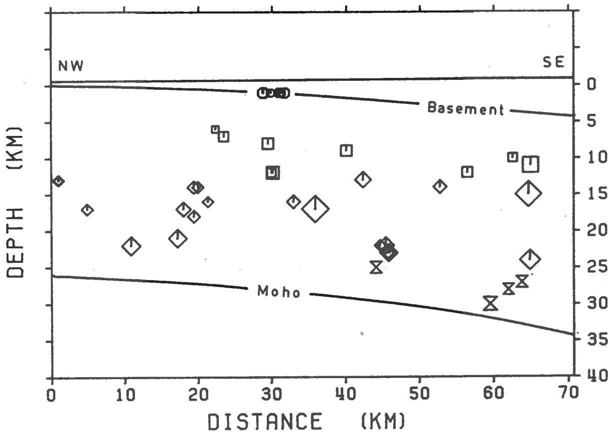

Figure 2: Focal depths projected onto a plane roughly parallel to the dip of the Moho. The different symbols correspond to different depth intervals and their size is proportional to the magnitude.

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THE NEW SPANISH SEISMIC NETWORK: OPTIMIZATION AND LOCATION CAPABILITY

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Abstract

The new Spanish Seismic Network will be composed of 25 homogeneous short period seismic stations distributed on the Iberian peninsula as well as in the Balearic Islands and Melilla (North Africa).

Because communication facilities forced to fix the stations sites, without previous optimum planning, optimization algorithms have been applied to calculate the best order of network extension from the eight new stations installed firstly. Location capabilities in the Iberian region of the new and the old networks are calculated and compared, together with a specific study in the seismically most active areas.

Finally, the new Spanish Seismic Network will give a remarkable location accuracy improvement with respect to the present one, for earthquakes in the Iberian region.

Introduction

The Spanish Seismic Network, as operating at present, is composed of 14 short period seismic stations (Figure 1) with different seismometer installations and recording devices well as independent time control clocks (see Mezcua and Martínez Solares, 1983). This instrumental inhomogeneity plays a remarkable role, not only in network running cost and data processing time, but also in the earthquake location capability of the network, besides the influence of seismic station - distribution.

In order to solve these problems, and thereby attempting to achieve improved earthquake locations in the Iberian region, the Spanish National Geographic Institute is carrying out a project to set up a new National Seismic Network. According to the importance of the seismicity in the area, it will be composed by 25 homogeneous short period seismic stations (Figure 2) which are connected by telephone lines with the data processing center of the Seismological Section of the National Geographic Institute in Madrid. Satellite timing system gives a common time signal and the data are recorded on digital magnetic tape (Galán, 1986).

Mainly because communication restrictions the 25 station sites have been chosen in advance, and housings for the field instrumentation were already built at these sites. Eight of these new stations are presently installed and running (Figure 2).

Seismicity

The seismicity of the Iberian region (35 N-45 N, 11 W-5 E) (Figure 3) is mainly concentrated south and south-east of the lower limit of the central stable part and in the Pyrenees to the north-east, with a weak seismic zone along the coasts of Portugal and northern Spain (Udías, 1980). West of the Strait of Gibraltar the rate of small earthquakes is lower than to the east, showing two seismically different zones at both sides of the Strait (Udías et al., 1976). At the coast of Morocco, earthquakes continue eastwards along the trend of the Tell Atlas mountains, through the coast of Algeria and Tunisia, with two concentrations in Oran and El Asnam regions (Girardin et al., 1977). The focal depth is not well known, and although some shocks may be as deep as 100 km. Most earthquakes are certainly of shallow depth, with the exception of two deep ones (h = approxi-mately 600 km) in southern Spain (March 25, 1954 and January 30, 1973) (Udías,1980).

From integration of seismicity distribution and tectonic data of the Iberian peninsula, 24 seismic source zones were defined to be used in the preparation of probabilistic hazard maps for the new Spanish Building Code (Figure 4). Seismicity parameters of these zones, such as the estimated maximum expected MSK intensity, the average annual rate and b-values of the earthquake intensity-frequency distributions, are given in Table 1 from the previous results of the Grupo de Trabajo de los Mapas de la Norma Sismorresistente (in preparation).

Seismic networks optimization and location capability

Besides instrumental requirements, the performance of a seismic network is closely related to the accuracy of earthquake locations. The errors encountered in detection and location are dependent not only on random and systematic ones, but also on the distribution of seismic stations. The influence of systematic errors can be eliminated by refining the parameters of the velocity models through detailed analysis of travel-time anomalies. The values of random errors can therefore be used as a quality criterion of the distribution of seismic stations.

ZONE	MAXIMUM INTENSITY (MSK)	YEARLY RATE	b-VALUE	WEIGHT
1	IX+	0.63	0.44	1.00
2	X	1.15	0.49	1.00
3	IX+	1.35	0.47	1.00
4	VIII	1.29	0.63	0.75
5	VI	0.60	0.78	0.50
6	X	1.18	0.49	1.00
7	IX	0.36	0.48	1.00
8	VII+	0.29	0.40	0.50
9	VII	0.19	0.52	0.50
10	IX	0.36	0.44	1.00
11	IX	0.74	0.53	1.00
12	XI	0.62	0.43	1.00
13	X	0.20	0.34	1.00
14	VIII	0.63	0.53	0.50
15	X	0.54	0.39	0.75
16	VII+	0.65	0.51	0.50
17	VII	0.38	0.46	0.50
18	VII	0.20	0.41	0.50
19	VII	0.10	0.35	0.50
20	VIII	0.15	0.49	0.50
21	IX+	0.88	0.48	1.00
22	IX	0.82	0.49	1.00
23	VII+	0.50	0.61	0.75
24	VIII	0.12	0.32	0.50

Table 1: Seismicity parameters and weights of the seismic source zones of the Iberian region (Grupo de Trabajo de los Mapas de la Norma Sismorresistente, in preparation). Explanation: Intensity values with + sign indicates half degree higher.

For a given model of the Earth's structure, random errors depend upon the accuracy of the readings of seismic wave arrivals and the geometry between the hypocenter and seismic stations. Consequently, the problem of optimum earthquake location is equivalent to an analysis of the spatial distribution of seismic stations, ensuring the minimal values of location random errors.

Probably the most comprehensive analysis of spatial optimization is that of Kijko (1978), who used the "D-optimal planning criterion" of Box and Lucas (1959). In general, this approach is directed towards minimization of the variances and covariances of unknowns in least-squares analysis, as a function of independent variables. This optimization method as well as the location capability analysis by Kijko (1977 b) have been applied in this study. Detailed explanations of the theoretical background can be found in Kijko (1977 a, b, 1978) and Hafidh et al. (1985).

Application and results

To represent seismicity in a quantitative manner, the seismic zones defined for the probabilistic seismic hazard maps of the new Spanish Building Code (Figure 4) were used. Different weights according to their estimated seismic activity (Table 1) have been assigned, in order to obtain the probability density of earthquake occurrence. It was assumed that the average earthquake focal depth in the region is 10 km.

From the average crustal model of the Iberian peninsula given by Mezcua and Martínez Solares (1983), a simplified model with two horizontal layers over a half-space was adopted (Figure 4). The standard deviation of arrival times was estimated as sigma(t) = 0.25 s for the old network stations and for the new network sigma(t) = 0.1 s, taking into consideration, that this last value could not be realistic in practice. Anyhow, the aim of these values is to make a distinction between the instrumentation quality of both networks.

Figures 5, 6 and 7 show the distribution of the standard error of epicenter location, sigma(xy), for the old network, the new one, and the eight stations of the new network already working, respectively. In these three cases it is assumed, that all stations in the network are recording the earthquakes in the Iberian region. That means, that an average value of threshold magnitude of about Ml=4.5 is recorded, as can be estimated from the instrumental seismic catalog (Mezcua and Martínez Solares, 1983). The Iberian peninsula is under the epicentral error isoline 1.5 km using the old seismic network (Figure 5), while with the new one it is under the 0.4 km isoline (Figure 6). Even with only the eight working stations of the new network, most of the Iberian peninsula is under the 1.0 km epicentral error isoline (Figure 7). The average epicenter location error, sigma(xy), in the Iberian region is 2.4 km for the old network and only 0.6 km for the new one. That is an improvement of 74 % in epicentral location.

OPTIMAL ORDER OF EXTENSION	STATION
1 st	ETER
2 nd	EMEL
3 rd	EGRA
4 th	EJIM
5 th	EMON
6 th	ESEL
7 th	EPRU
8 th	EZAM
9 th	EEBR
10 th	ECRI
11 th	EALH
12 th	ERUA
13 th	EBAN
14 th	EVIA
15 th	ECHE
16 th	EHUE
17 th	ETOR

Table 2: Optimal order of network extension from the eight already installed new stations.

As the station sites of the new seismic network had been previously fixed, because restrictions due to communication facilities, an optimum planning of the network before installation was not possible. Nevertheless, optimization algorithms were applied to calculate the best order of network extension from the first eight installed new stations to the 25 stations - network planned. In such a way, there is a advanced information about which stations should be set up first, to assure minimal location errors. As shown in Table 2, the first ones to be installed should be the stations in the north-eastern part of Spain and the station in Melilla (North Africa).

The south-south-eastern part of the Iberian peninsula (between 36 N-39 N and 7 W-0 E) can be considered as the seismically most active one. Seismic zones 1 to 10 (Figure 4) are included there. Zones 2, 3, 4 and 6 are the ones with larger average yearly rate, and zones 1, 2, 3, 6, 7 and 10 having estimated maximal intensity bigger or equal to IX (MSK) (Table 1). Moreover, several critical facilities are in or close to this region (i.e. 15 of the largest dams in Spain are located in the area (Buforn and Udías, 1979) and four nuclear power plants are located between 80 and 25 km above 39 N). Therefore earthquake locations in this area should have enough accuracy, corresponding to the importance of the regional seismicity. This SSE region was chosen to calculate the location capability of the three seismic networks considered before, but assigning now a detection distance of 300 km to each station in order to get into a more real situation. That means, that if the epicentral distance is more than 300 km, this station is rejected in the calculations. In this case we reduced the average value of threshold magnitude to about Ml=3.5.

Figures 8a,8b and 8c are contouring maps of epicenter location standard error sigma(xy), in the SSE part of the Iberian peninsula for the old seismic network, the new one and the actually working eight new stations, respectively. The largest error isoline, covering most of the area, is 2.5 km for the old seismic network (Figure 8a), 1.0 km for the new network (Figure 8b) and 2.0 km for the eight new stations network (Figure 8c), that means an epicentral location improvement with respect to the old seismic network from 20 % with the eight new stations and 60 % with the complete new network. Nevertheless, as shown before for the entire Iberian peninsula, with the new seismic network most of the region is under the error isoline 0.4 km (Figure 8b), even with the detection distance of 300 km.

Conclusions

The new short period Spanish Seismic Network will give a remarkable improvement in location capability compared to the present network for different magnitude thresholds (epicentral location improvements are between 60 % and 74 %).

Even the eight stations of the new seismic network, which are already working, give now some increase in location accuracy comparing with the old seismic network (between 20 % and 33 % improvement).

Despite the missing optimum planning of the new seismic network before the installation, the optimum progress of the further extension of the network still provides minimal epicentral location errors.

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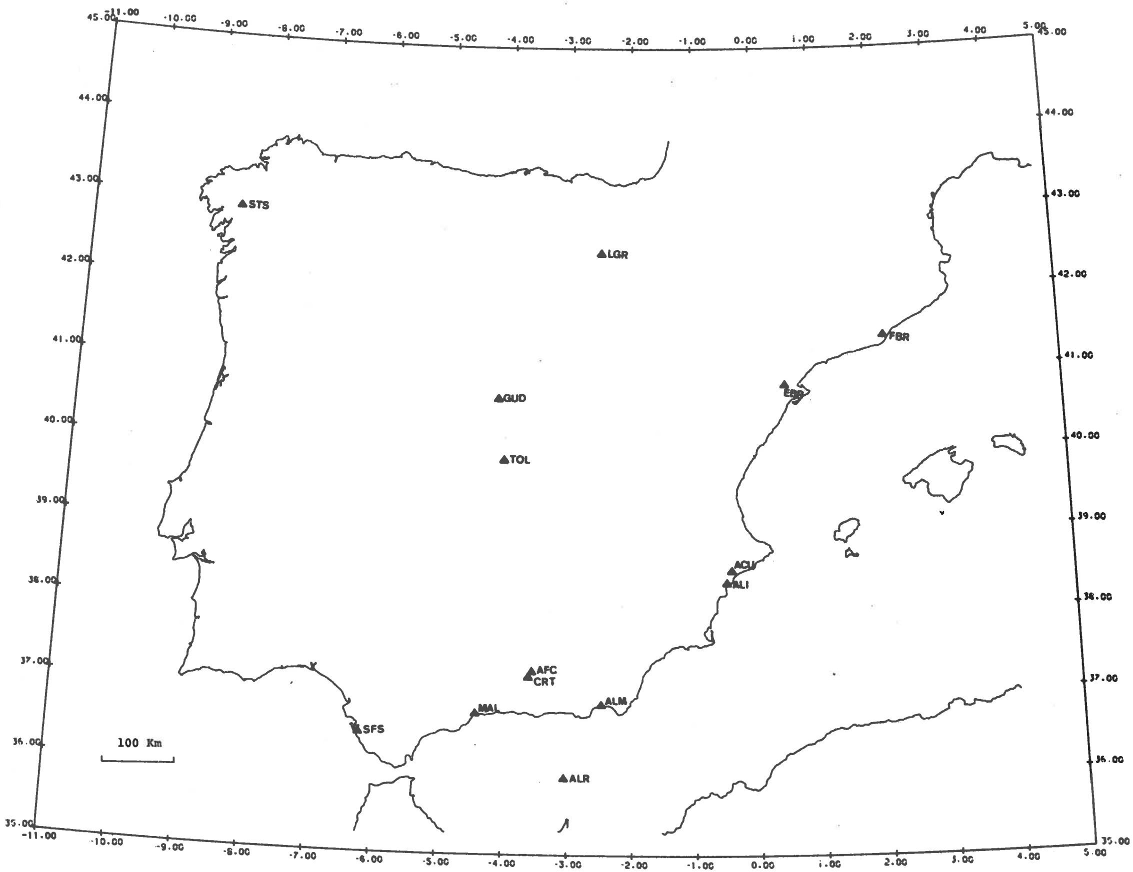


Figure 1. Seismic stations of the old Spanish Seismic Network.

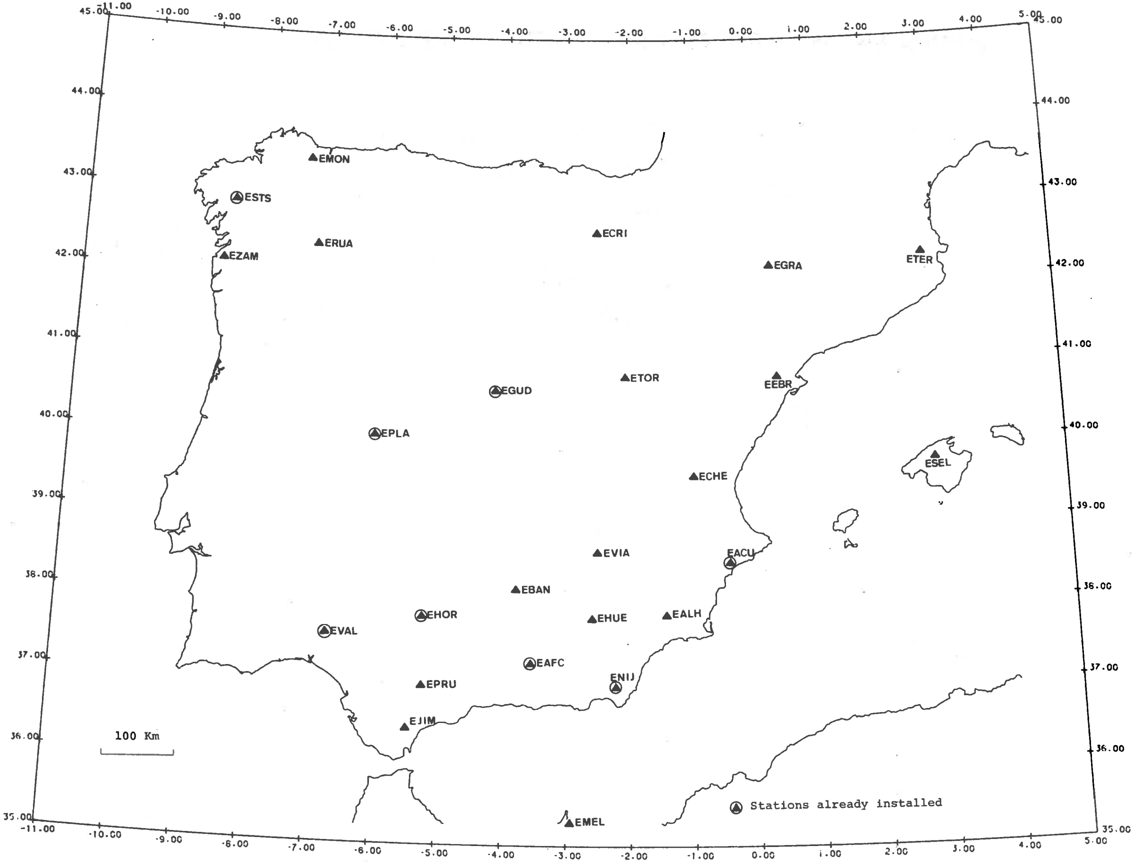


Figure 2. Seismic stations of the new Spanish Seismic Network. (Station codes are provisional).

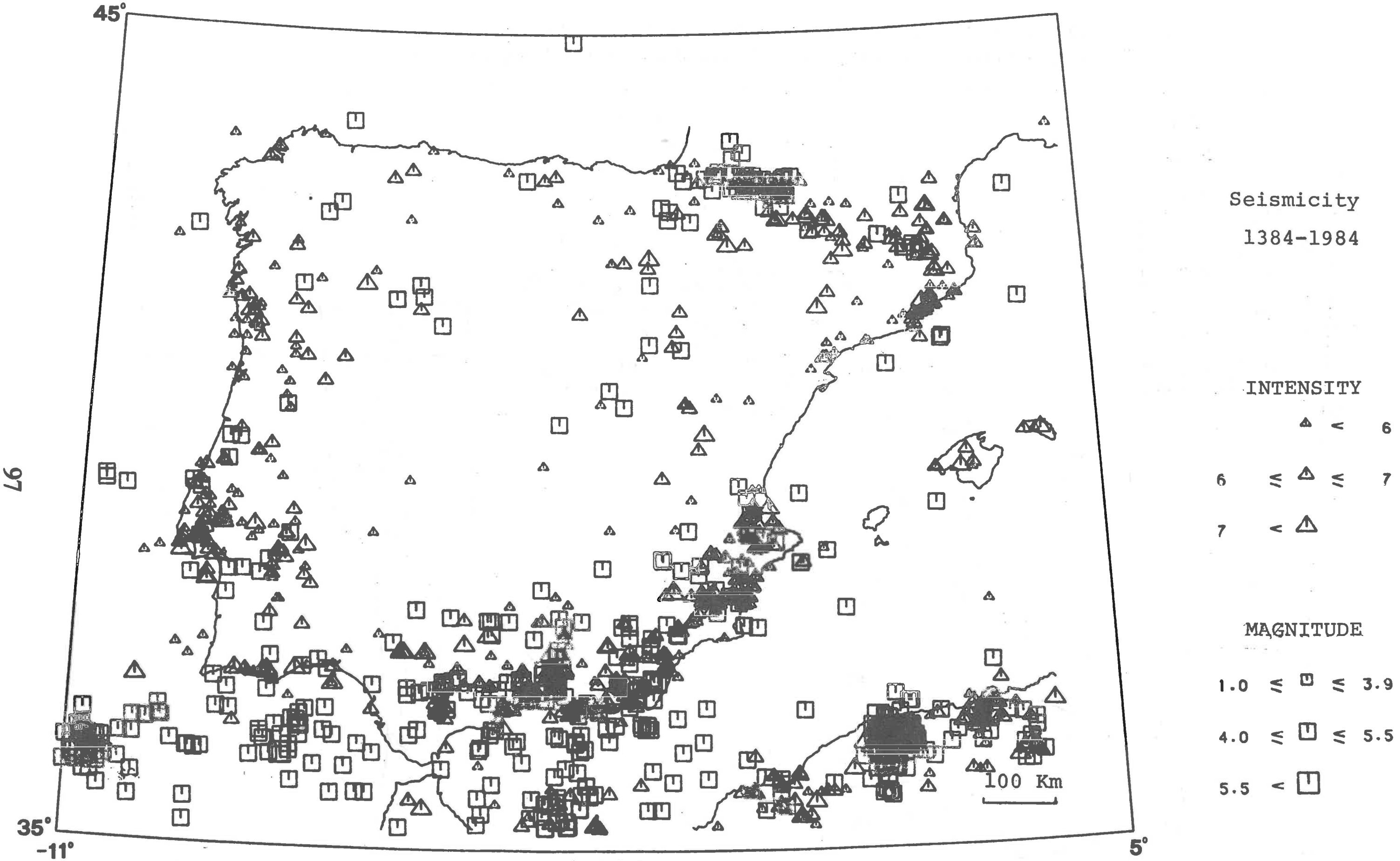


Figure 3. Seismicity of the Iberian region.
Intensity period of data: 1384-1950 (I (MSK) >= V)
Magnitude period of data: 1951-1984 (Ml >= 4)

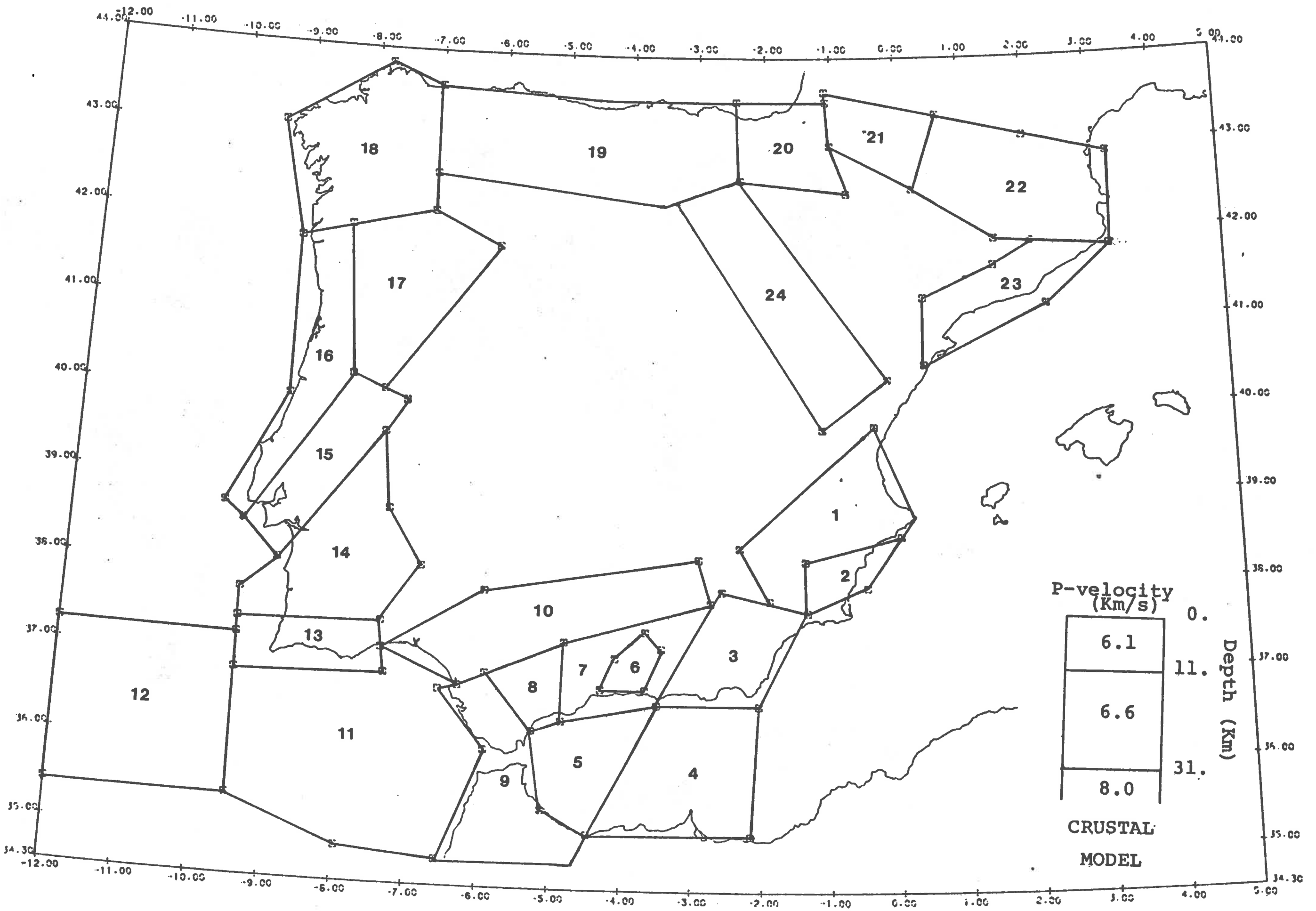


Figure 4. Seismic source zones (Grupo de Trabajo de los mapas de la Norma Sismorresistente in preparation) and simplified crustal model.

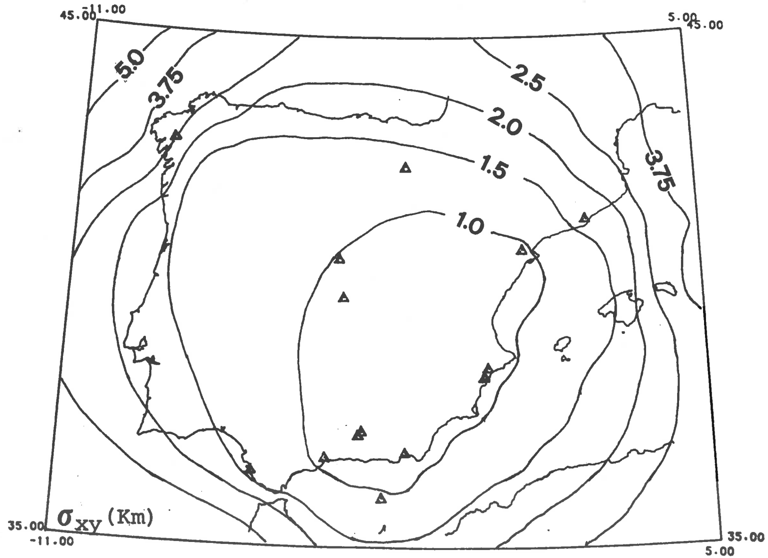


Figure 5. Standard error of epicenter location in the Iberian region for the old Spanish Seismic Network.

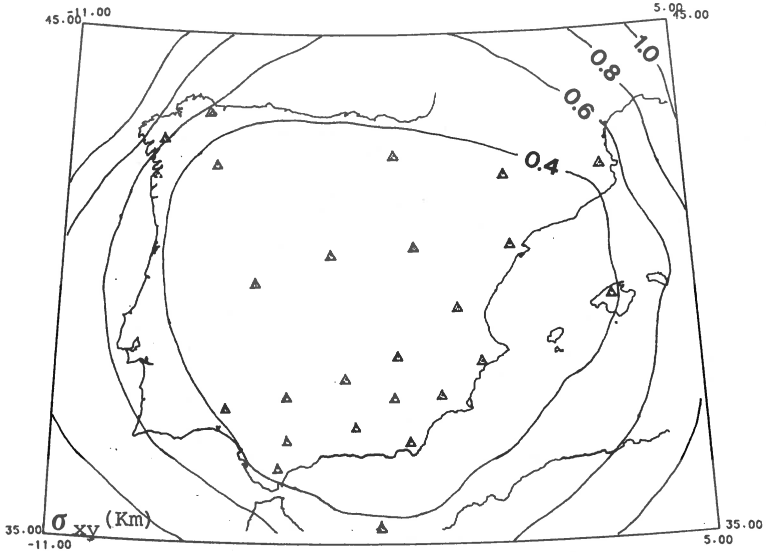


Figure 6. Standard error of epicenter location in the Iberian region for the new Spanish Seismic Network.

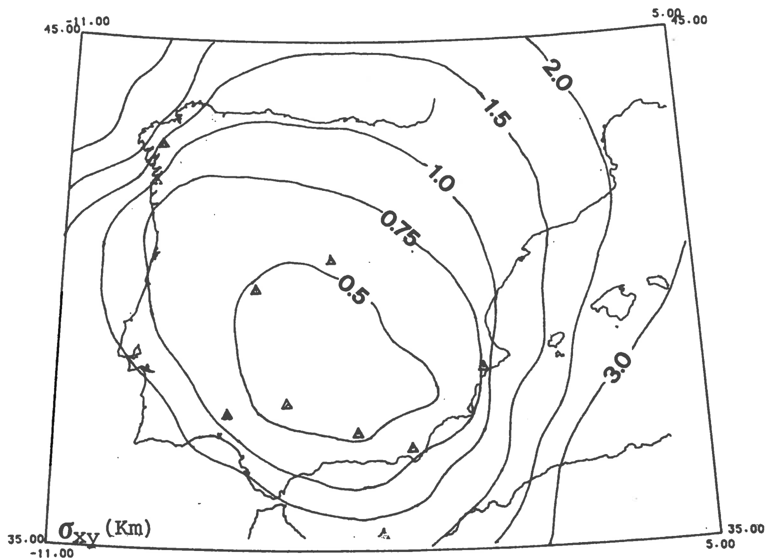
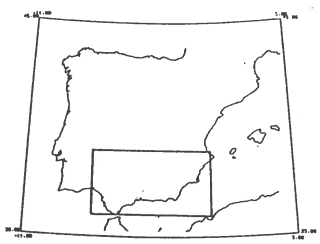
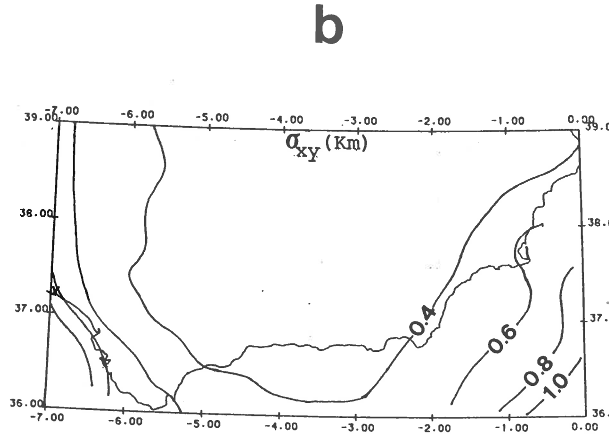
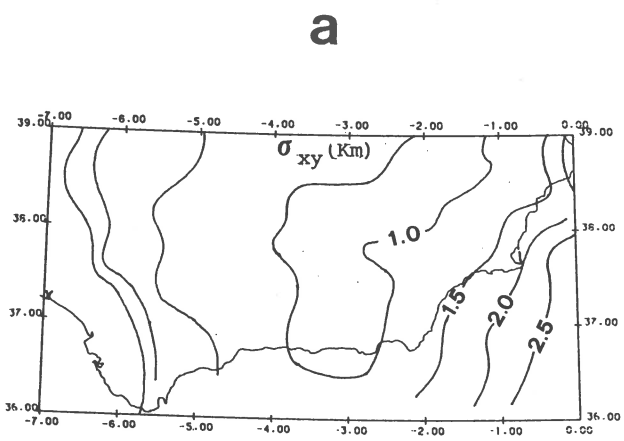


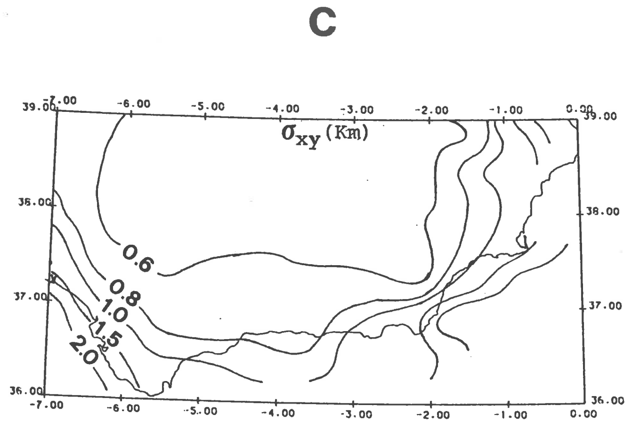
Figure 7. Standard error of epicenter location in the Iberian region for the eight stations of the new network already working.

Figure 8. Standard error of epicenter location in the S-SE part of the Iberian peninsula considering a detection distance of 300 km.
(a) Old Spanish Seismic Network
(b) New Spanish Seismic Network
(c) Eight new stations









THE GENERATION OF MICROSEISMS IN THE COASTAL ZONE

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This study considers the properties of microseisms within the range of 3-8s periods in Kamchatka. Analysis and comparison of similar properties is made for sea in the coastal zone to determine the most probable mechanisms of the microseism generation. The experimental dependence of the amplitude of microseisms on period is shown to agree well with the theoretical estimates. Comparison of dependences of vertical and horizontal components of microseisms on periods points to the difference in these dependences that may testify to the different mechanisms of generation. The theoretical estimates enable us to consider with confidence that the horizontal component of microseisms is generated at the expense of near-floor friction, whereas the vertical component is generated by the near-floor pressure. Zones of generation of both components coincide, being within a shallow coastal band (down to depths of the order of half wavelength).

MONTE-CARLO SIMULATION OF RECORD ENVELOPE OF THE NEAR EARTHQUAKE

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An analytic technique is lacking now to model even qualitatively the realistic record envelope shape of a near earthquake at frequencies of 1-20 Hz. The known single and multiple isotropic scattering models predict a pulse-like direct wave ata distances up to several L (L is the mean free path), whereas the observed "direct" wave group is evidently widening with distance. Layered models fail to predict realistic coda envelope shape.
Monte-Carlo simulation of the envelope shape was carried out for acoustic pulse in scattering half-space. Isotropic and anisotropic (indicatrix half-width = 25°) cases were studied. The "source" pulse is observed up to r = 3 L in isotropic case (IC), in anisotropic case (AC) it is not seen even at $r>r0\approx10$km. The width of the "direct" wave group increases as r^2 in AC at $r0<r<L$ and no clear group is seen further in agreement with observations.
The simulated amplitude-distance curves were corrected for realsitic absorption and instrument effects and then compared with several empirical calibration curves for near earthquakes. No good agreement was observed for the initial half-space mdoel. However, when the probable layered L - Structure was taken into acount (in rather approximate way), a reasonable agreement was achieved.

SEISMICITY AND SEISMIC HAZARD IN ICELAND

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Iceland is located on the mid-Atlantic Ridge, and the seismic activity there is mainly related to the ridge. In southern Iceland and near the north coast we have something like transform faults. Most of the destructive earthquakes in Iceland occur in these regions.

The first and for a long time the only study on seismic hazard in Iceland was made by Tryggvason et al. (1958). But recently some studies have been made on seismic hazard, both in general (Sólnes, 1985) and for special sites for engineering purposes (Halldórsson et al. 1984 and 1986).

Now we are working on analysis of seismic risk in Iceland. The first steps we present here are:

(1) To compile a catalogue of seismic events in Iceland

(2) To calculate the attenuation of earthquake intensities in Iceland

(3) As a result of (1) and (2), statistical analysis of the seismic hazard

Compilation of a catalogue of seismic events

Several studies have been made on seismicity and historical earthquakes. In the years 1899 and 1905 Thoroddsen published a treatise on historical earthquakes based on historical material available at that time. Later he gave a shorter overview (Thoroddsen, 1925). These are still the fundamental works on this subject. Another studies of historical earthquakes have been published by Þórarinsson (1937), Tryggvason et al. (1958), Tryggvason (1973), Björnsson and Einarsson (1974), Petersen et al. (1978), Stefánsson (1979), Einarsson and Björnsson (1979), Guðmundsson and Sæmundsson (1980) and Einarsson et al. (1981).

The following table gives an overview of available sources for earthquake catalogue at different periods. To get an acceptable figure of the seismicity in Iceland, instrumental data are insufficient. By using only instrumental data we would for example lose the last great earthquake sequence in the South Iceland Lowland in 1896.

Sources of an earthquake catalogue

1100 - 1700	Historical, unreliable
1700 - 1900	Historical, most earthquakes $M \geqslant 6$, known in neighbourhood of inhabited areas
1900 - 1926	Instrumental, most earthquakes $M \geqslant 5$
1926 - 1951	" , " " $M \geqslant 4$
1951 - 1964	" , " " $M \geqslant 3$
From 1964	" , all earthquakes $M \geqslant 2$

Historical sources mostly mention earthquakes in connection with damage caused by them. As discussed later in this paper the attenuation of seismic intensity is strong in Iceland. As an example, from an earthquake with magnitude 7 we can expect the intensity VII in 40 km distance from epicenter. Therefore, the historical sources are limited to large earthquakes in neighbourhood of inhabited areas.

To use historical earthquakes for statistical studies we have to compare our knowledge of tectonics and seismicity from this century with the historical sources.

Short overview over the seismicity

In Fig. 1 all known earthquakes from 1700 with magnitudes greater than 6 are plotted. The magnitudes are estimated from the destruction zone. The magnitudes and locations of earthquakes on and off north Iceland are taken from Tryggvason (1973). For comparison all measured earthquakes $\geqslant 4$ from 1926 to 1980 are plotted in Fig. 2.

These figures show that the main seismic zones are in south Iceland and on and off the coast of north Iceland. Smaller events are also very frequent on the Reykjanes Peninsula.

From these maps it is obvious how the mid-Atlandic plate boundary crosses Iceland. Southwest of Iceland the boundary follows the crest of the Reykjanes Ridge. Within Iceland the plate boundary is displaced twice. Transform fault features are disposed both in north and south Iceland.

On the Reykjanes Peninsula the movements seem to be partly aseismic and connected with volcanism. The seismicity there is characterized by frequent but rather small events. In the period from 1926 to 1980 there are 115 events in the interval 4.0 - 4.9 and 11 events have magnitudes 5.0 - 5.9. Two quakes have magnitude 6.0 and one magnitude 6.2. Fig. 1 shows no event in this region before 1900. Some historical events are known in this region. Their magnitudes have not been estimated, but they are hardly larger than 6.2.

The displacement of the plate boundary continues in south Iceland. In South Iceland Lowland there is no volcanism and the movement is mostly seismic. This is a inhabited area, and therefore we have reliable records of all major events ($M \geqslant 6$) at least since 1700. There we have historical events up to magnitude 7.1 as shown in Fig. 1. Since 1912 no greater event has occurred there, and according to Fig. 2 the last decades are relatively quiet.

East of the South Iceland seismic zone, the plate boundary goes through the country to the north coast. This part of the boundary is mainly characterized by volcanism and aseismic movements. According to Fig. 2 the seismicity there is low and the events rather small, with exception of the northern part of Vatnajökull, where earthquakes have reached magnitude 5.3.

Off the north coast the plate boundary is displaced to west and north of Iceland it follows the crest of the Kolbeinsey Ridge. It is obvious from Fig. 1 and 2 that this displacement is connected with large earthquakes. Fig. 1 shows

10 earthquakes greater than 6 off the north coast. Five of them occurred in this century, four in the last century but only one in the eighteenth century. This indicates that our knowledge about historical events in this zone is insufficient. The reason is that many earthquakes there cause no or little damage due to their distance from inhabited areas.

Attenuation of seismic intensities

As yet no strong motion data are available in Iceland. Therefore all our informations about strong motion are in terms of macroseismic intensities, according to the modified Mercalli intensity scale of 1931.

The intensity attenuation characteristic is an important factor both in study of historical seismic events and in seismic risk evaluation. To study the intensity attenuation in Iceland, 8 earthquakes have been used (Halldórsson, 1984). The epicenters of these earthquakes are distributed over all seismic zones in the country and their magnitudes are from 5.2 to 7.0. The method of Chandra (1979), was used to estimate the attenuation characteristics, and the data for analysis were taken from isoseismal maps. From these 8 earthquakes, attenuations of 25 epicentral distances, from 25 to 204 km, were used for analysis. In Fig. 3 the attenuations are plotted vs. distance. The best fit attenuation - distance relation is:

$$I_0 - I = 0.8767 - 0.00123R - 1.5691 \log R$$

The relation between I_0 and magnitude was found to be:

$$I_0 = 0.33 + 1.24M$$

where R is the epicentral distance, I the intensity at that distance and I_0 is calculated epicentral intensity. The standard deviation is about 0.2. The intensity - distance relation is shown in Fig. 3. This relation indicates a mean depth about 5 km for the earthquakes used in the study. This agrees with the assumption that most earthquakes in Iceland have a similar depth, i.e. about 5 - 10 km.

It is a fact that the attenuation distance relation is not independent from the method used to get it. According to Chandra (1979), a calculated value is used for the epicentral intensity in this study. Most authors use the maximal intensity observed in the epicentral region, which is normally higher than the calculated intensity and gives therefore higher attenuation. The reason for this difference seems to be that the geological effects are overestimated in the modified Mercalli intensity scale.

In Fig. 4 the Icelandic results are compared with results from 3 other regions. For reasons just mentioned, only results calculated with the same method have been compared. The attenuation relations for Iran, San Andreas region and eastern U.S. are taken from Chandra et al. (1979). This comparison shows relatively high attenuation of intensities in Iceland.

The seismic hazard

The hazard analysis is based on all known earthquakes with magnitude 5 or greater in the period from 1700 to 1980. The intensity of the earthquakes was calculated for each point in a $0.5^{\circ} \times 0.25^{\circ}$ grid (25 by 27 km) for most of the country and in a $0.2^{\circ} \times 0.1^{\circ}$ grid for the southwestern part.

The distribution of the intensities was analyzed at each point by the Gumbel`s extreme value method. The third Gumbel`s distribution was used (Burton, 1979). The 280 years period was divided in 28 intervals, each lasting for 10 years, or 20, 14 years intervals, and the greatest event in each interval used for analysis. The result is presented in Fig. 5.

It is obvious from Fig. 5 that the most dangerous seismic zone in Iceland is in south Iceland. There we can expect earthquakes up to magnitude 7.2, and in about 900 km^2 area we can expect intensities over 7 every 100 years. The latest great event in this region occurred in 1912, in its eastern part. But a great majority of the region has not moved since 1896. It makes the situation serious that the South Iceland Lowland is an inhabited area and is relatively densely populated. In addition it is not far from the most important power-stations of the country. As mentioned before, the data for south Iceland are relatively reliable.

The data for Reykjanes Peninsula and north Iceland are less reliable than the data for south Iceland. The historical sources, which are now availible for earthquakes in thise regions are incomplete, and the hazard therefore probably underestimated. According to Fig. 5 we can at least expect the intensity 6.0 to 6.5 in Reykjavík and surroundings, once every 100 years. About 60% of the population of Iceland lives there. The same can be expected in north Iceland. To make more accurate hazard estimate for these regions it is necessary to analyze shorter time intervals as well as investigate historical earthquakes.

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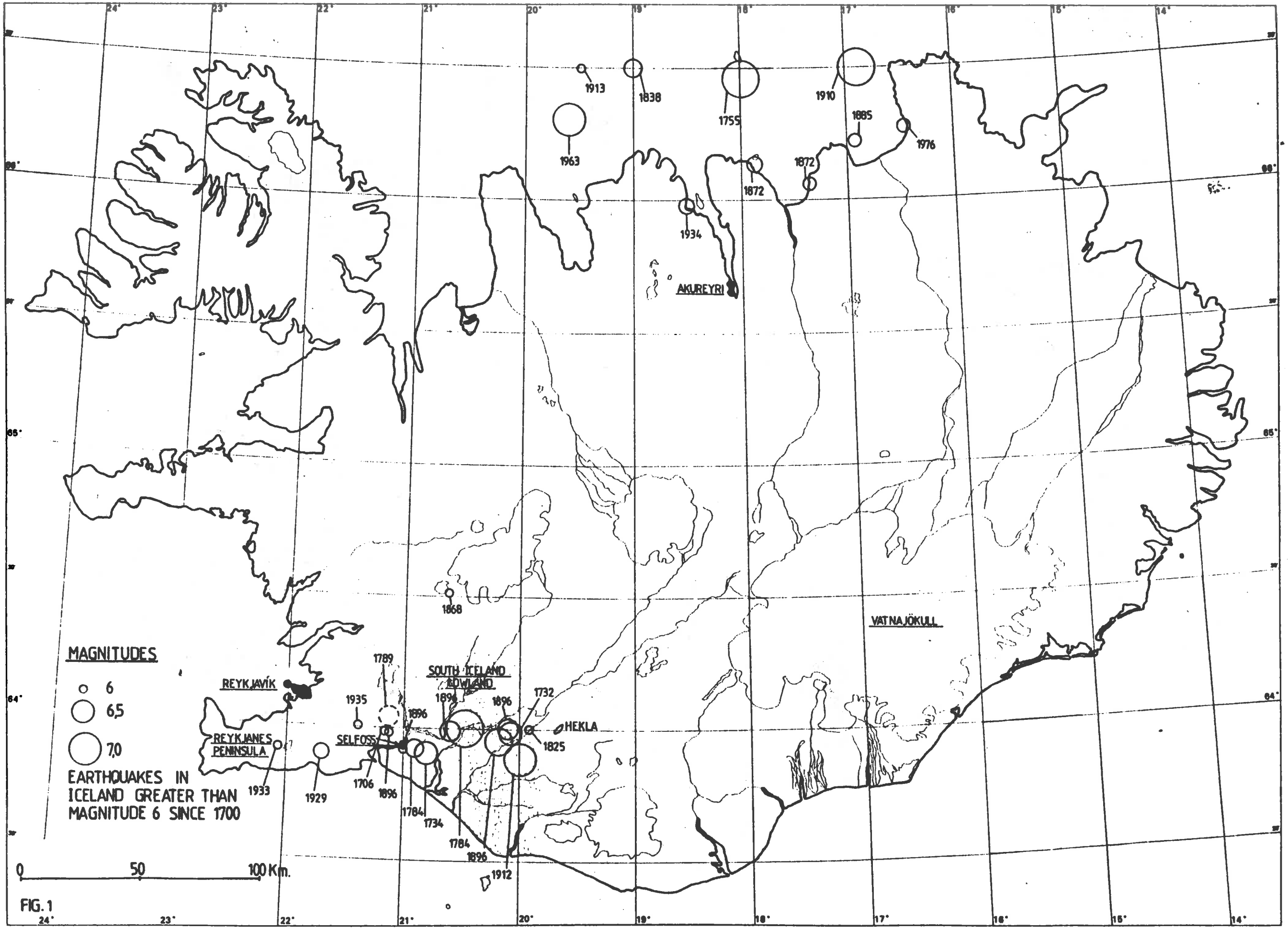

MAGNITUDES
6
6,5
7,0
EARTHQUAKES IN ICELAND GREATER THAN MAGNITUDE 6 SINCE 1700
0
50
100 Km.
REYKJAVÍK
REYKJANES PENINSULA
SELFOSS
SOUTH ICELAND LOWLAND
HEKLA
AKUREYRI
VATNAJÖKULL
1913
1838
1755
1910
1885
1976
1963
1872
1872
1934
1868
1789
1935
1896
1896
1896
1732
1825
1933
1929
1706
1896
1784
1734
1784
1896
1912
24°
23°
22°
21°
20°
19°
18°
17°
16°
15°
14°
66°
65°
64°
FIG. 1

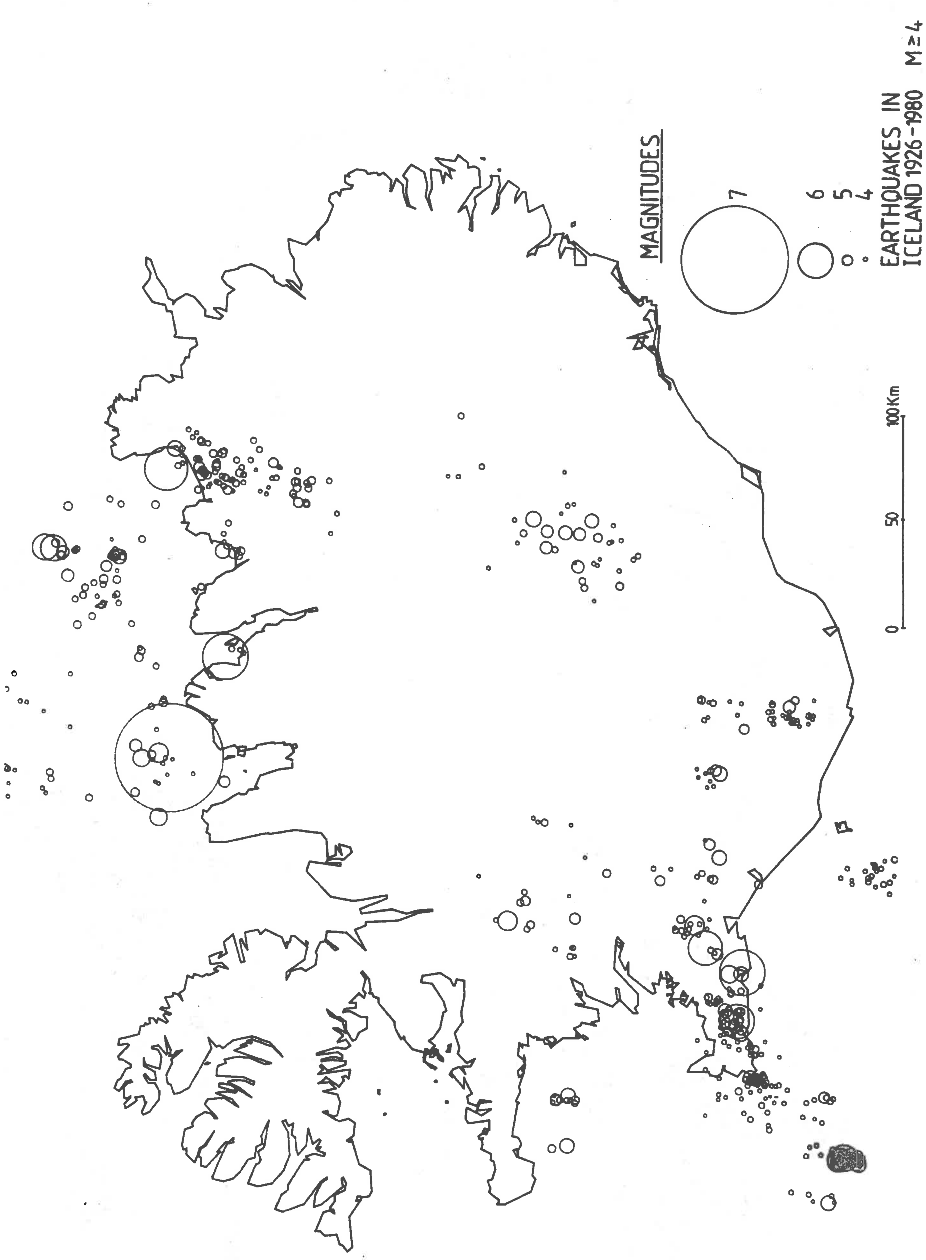

MAGNITUDES
7
6
5
4
EARTHQUAKES IN
ICELAND 1926-1980 M ≥ 4
0
50
100Km

FIG. 2

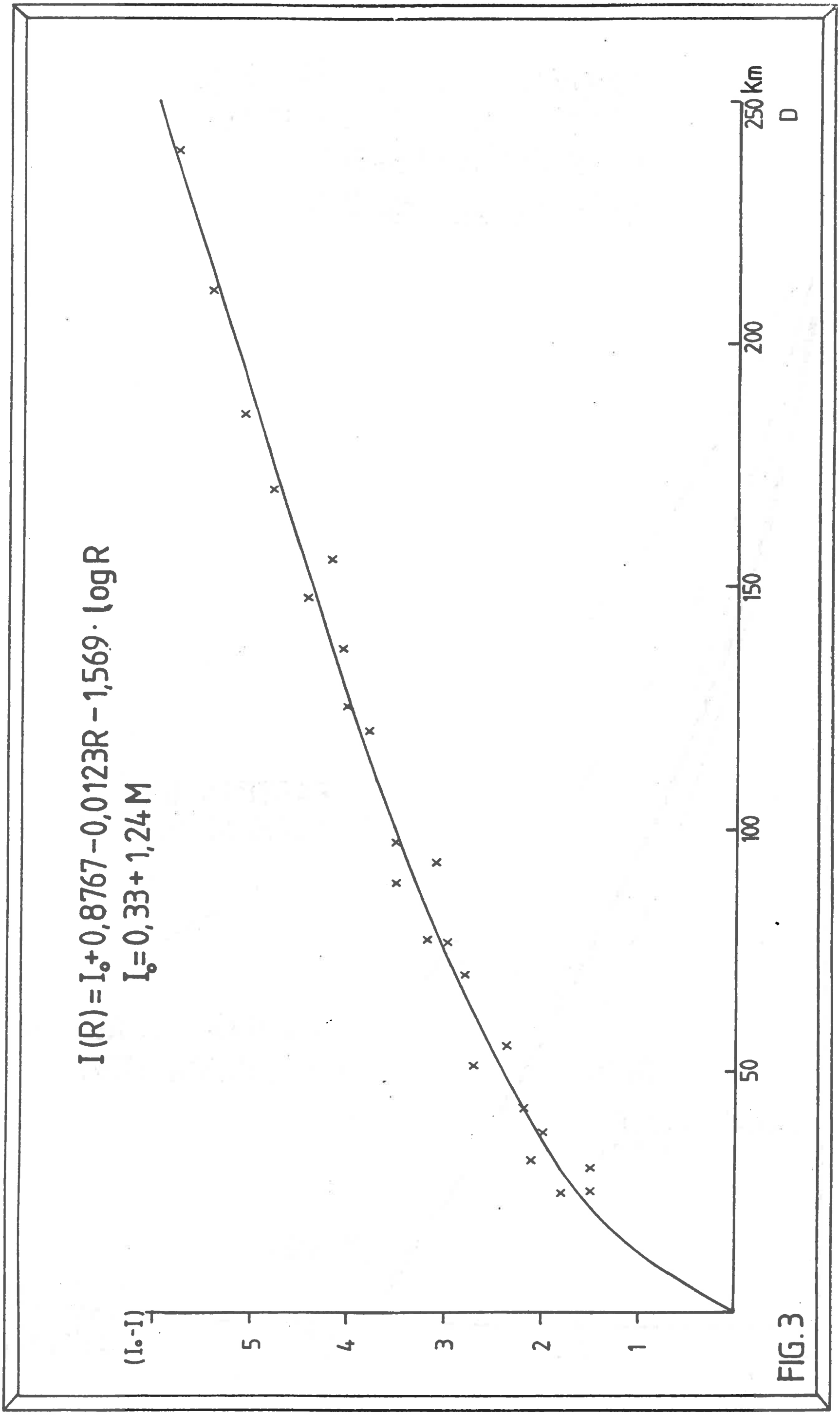
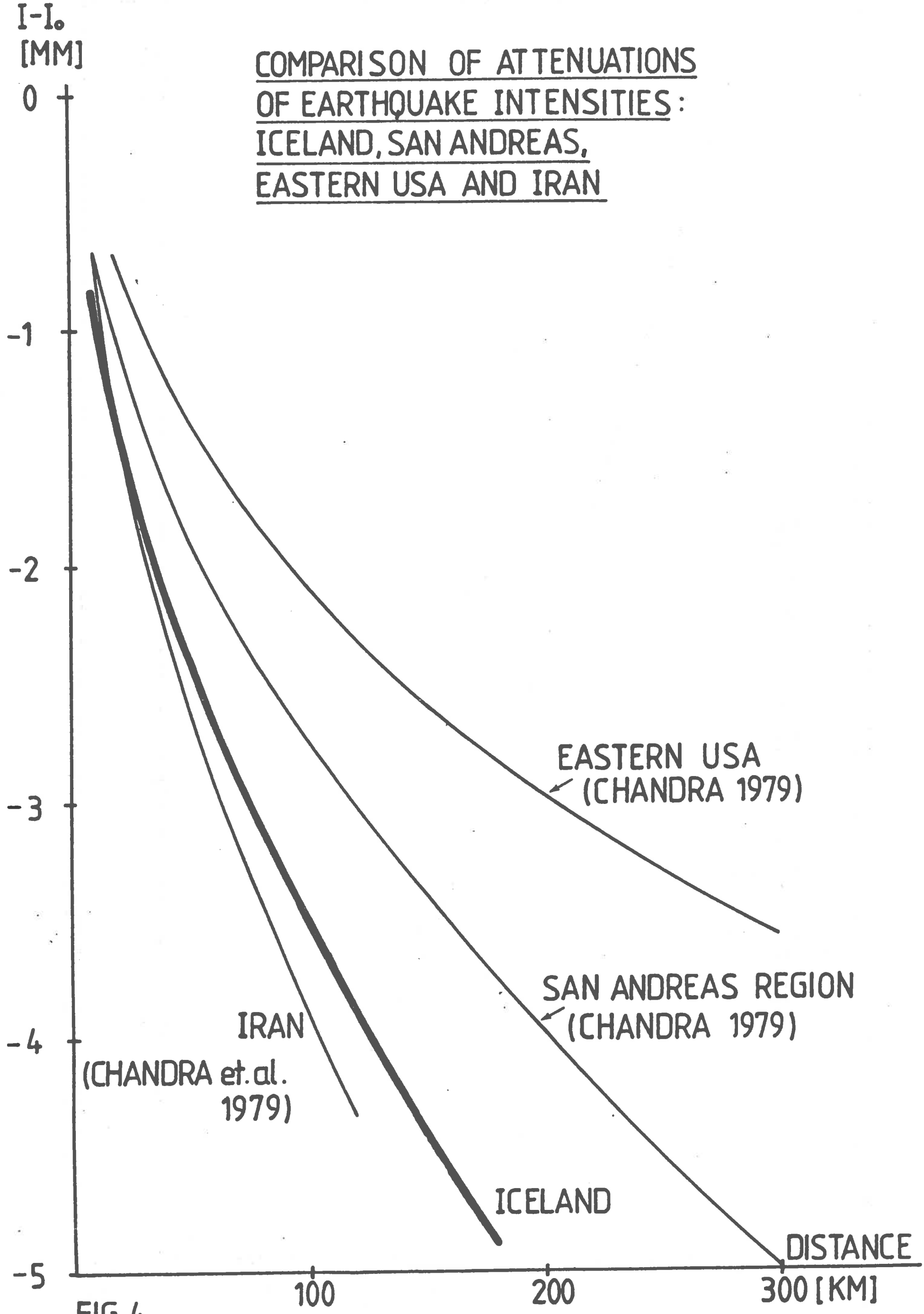
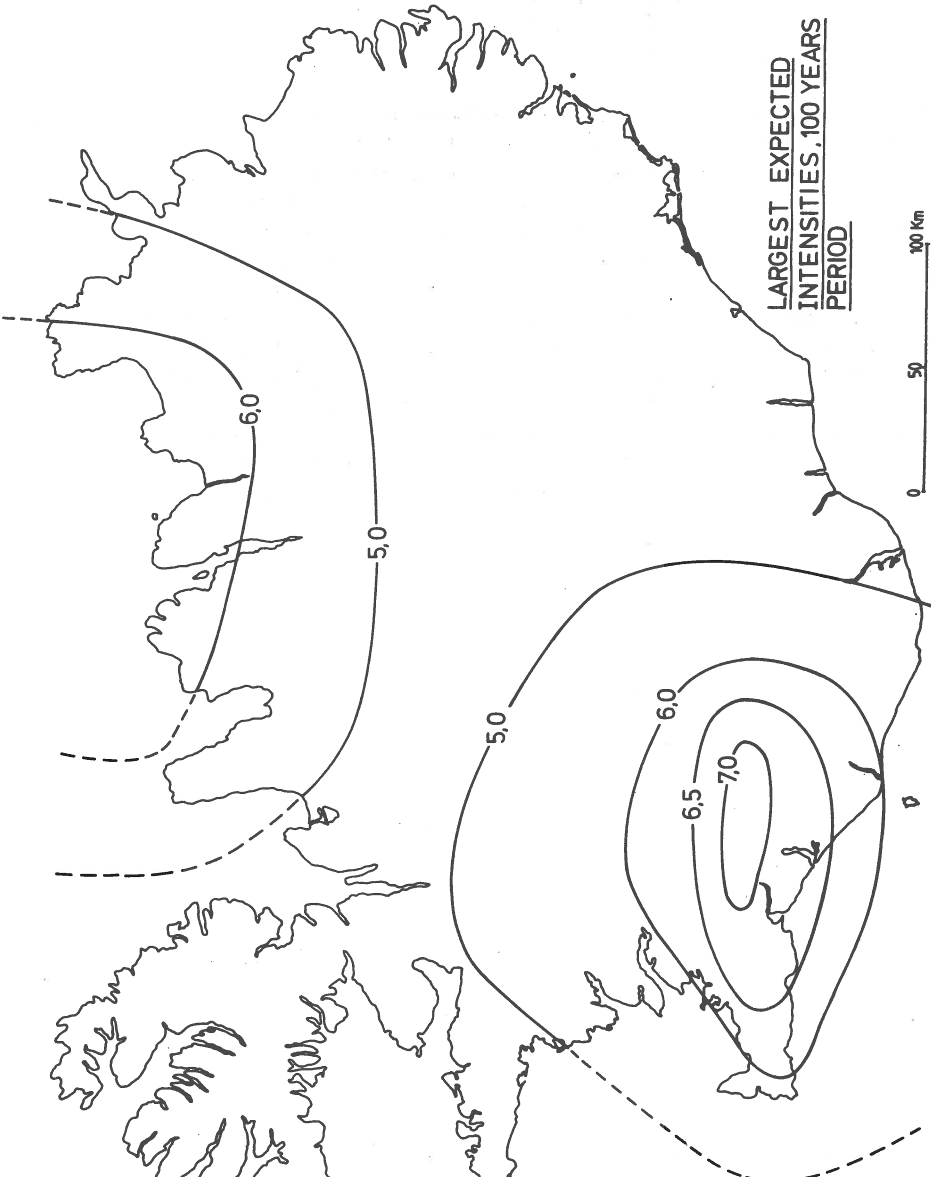

I(R) = I₀ + 0,8767 − 0,0123R − 1,569 · log R
I₀ = 0,33 + 1,24 M
(I₀-I)
1
2
3
4
5
50
100
150
200
250 Km
D

FIG. 3



I-I₀
[MM]
COMPARISON OF ATTENUATIONS OF EARTHQUAKE INTENSITIES: ICELAND, SAN ANDREAS, EASTERN USA AND IRAN
0
-1
-2
-3
-4
-5
EASTERN USA (CHANDRA 1979)
SAN ANDREAS REGION (CHANDRA 1979)
IRAN (CHANDRA et.al. 1979)
ICELAND
DISTANCE
100
200
300 [KM]

FIG. 4



LARGEST EXPECTED INTENSITIES, 100 YEARS PERIOD

FIG. 5

SHORT PERIOD NOISE MEASUREMENTS FROM A WORLDWIDE EXPERIMENT.

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Geodetic Institute, Gamlehave Alle 22,
DK-2920 Charlottenlund, Denmark.

A data set has been extracted from the messages exchanged during a world wide Technical Test carried out by the Group of Scientific Experts in Geneva. The data set consist of maximum noise amplitude and corresponding period read prior to each P reading. The joint distribution of amplitude and period for such data was already presented at the IASPEI meeting in Tokyo, 1985, and will be included in a publication in Physics of the Earth and Planetary Interiors. The joint distribution was also presented in Kiel, and it was shown that apart from a limited number of measurements from very quiet and from very noisy stations, the values fall within the Brune and Oliver curves. It was also argued that information on seismic noise variations can be obtained by this type of measurements, and further work is planned using an improved data base from that experiment. The data base is improved by including messages not received here but at Experimental International Data Centers.

A Seismic Network with Loosely Coupled Remote Stations

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(both at: Ruhr-University, Bochum, F.R. Germany)

I. Introduction

The 'Ruhrgebiet' is the largest coal mining area of West Germany and extends 40 km NS and 80 km EW (fig. 1). About 1.000 mining tremors per year with local magnitude ≤ 2.5 are recorded by the BUG (Bochum University Germany) network, consisting of a small tripartite array and two remote stations equipped with three-component short-period instruments.
Usually digital seismic networks are built with closely coupled remote stations, that transmit data to the central station in realtime and continously. Remote analog-to-digital conversion is representative for "second generation" digital networks (fig. 2). The rapid development in computer techniques calls for a further step in seismic network design, which largely extends the tasks of the remote stations. In this "third generation" networks the remote stations are only loosely coupled and the central station plays the role of a supervisor. The BUG-network is an example for this new approach.

II. Station Dialog

All remote stations work completely independent from the central station. They consist of (fig. 3):
- the data aquisition electronics including an analog-to-digital converter and a local time base
- the temporary data base, made up by the time-stamped data records circulating in a FIFO manner
- the permanent database
- the detector algorithm
- the dialog frontend for communication with the central computer in the observatory.

The remote data bases can be manipulated by commands from the central station via DIALOG or from the local detector (only SaveD).
A typical example for a dialog after some seimic activity is (fig. 4): Stations R1 and R3 send an event-message to the coincidence detector at the central station and save locally the appropriate data records. Now depending on the decision of the coincidence detector,
- if false, the data records have to be removed from the local permanent databases in R1 and R3 by a PurgD-command
- if true, the two stations R2 and R4, that missed the event, have to receive a SaveD, before the data records in the temporary database

are overwritten.
The finite length of the FIFO, i.e. the size of computer memory and remote disk space, determines the maximum response time. It varies from some 10 minutes to several days. The SaveD-command is the only time-critical process in the whole station network, so all the communication can be done in an off-line way.

The organisation of the time series in a database allows an easy extension to different data types (fig. 5). In the BUG-network the original data are sampled at 100 Hz with 16 bit dynamic range. A second data type uses 8 Hz sampling frequency and 8 bit dynamic range. This is only 4% of the original data volume , but still sufficient for a simulation of a permanent monitor recording (e.g.Helicorder). The amplification of this monitor record can simply be switched by software (amplification in steps of two can be done by shift command).

Data transmission is only one part of the more complex off-line dialog process. Other tasks are detector messages, status reports and download of new detector algorithms (fig. 6), these are treated as a special data type in the data base. A Reset-command starts the remote station with the new detector process.

The BUG-network was finally installed in the beginning of 1986. Fig. 7 gives an example of a rockburst, KLB, SHA and TEZ are the stations of the tripartite array at Bochum (epi.dist. = 40 km), HRH is the station east of Dortmund in a coal mine 1000 meters below the surface (epi.dist. = 4 km), the local magnitude is 1.7 . An example of the monitor simulation is given in fig. 8, it shows in reduced scale the first 6 minutes of each trace of 30 minutes. The orginal scale is 6 cm for 1 minute, the recording is 1.8 m long. Due to the data reduction, the transmission takes only a few minutes for each displayed hour.

The concept of loosely coupled remote stations with a station dialog is a result of the increased performance of modern microcomputers. Fig. 9 gives a comparison of this development since 1978 and tries to extrapolate to 1990. The main contraint for the near future is the expensive data transmission, so one task for the local processor is minimize data tranport in the network. Data transmission on demand only and appropriate data types are two ways of reaching this goal.

III. Layer Architecture

The tasks of a seismic network can be separated into three main areas:
- data aquisition
- data management
  (it includes optimisation of data transmission and transparent access) -
data processing
  (interactive and automatic event detection and determination)

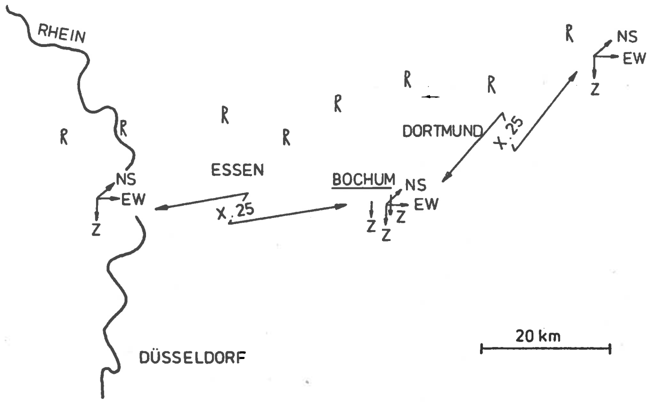
Only the last task is of vital seimological interest, while especially the data management with all details of computer networking and complicated database organisation can be left to computer specialists. A separation of these tasks into different planes of a layer model (fig. 10) will help to concentrate on scientific questions. Each lower level performs some service functions for the higher one so different physical networks can be used in level 3 (LAN, X.25, V.23, SHM), as long as they provide the same service.

Conventional seismic networks can not use all possible layers especially the dialog is missing, database queries are nothing more than searching on an event tape in the observatory (fig. 11). The first complete realisation of all levels of the layer model was implemented in the BUG-network (fig12). Transparent for the seimologist there are two different computer networks, based on short haul modems for the local array at university site and on X.25 for the remote stations in the coal mines.

In such an environment the seismologist is only concerned with the highest level of a network which might be very sophisticated in detail. All the important informations are included in a detector and a network listing (fig. 13). This listing is a directory of all stations, it defines the saved data windows for a subset of stations depending on the type of event, the automatically plotted waveforms, the transmitted data for the helicorder recording with the amplification level and the default detector algorithms for each station.

Additional advantages of the layer model are easy maintenance, since the technical staff has to care only about the lower three levels, and easy development. The modular form of layer services allows adaption to special problems at different seismometer sites and allows an easy update of computer components and software at lower levels without changing the overall behaviour of the user shell.

Even complex systems like a network of several observatories, which want to share a common database in realtime, can be described quite easyly in the layer model (fig. 14). Each observatory defines its own interest in the available data by an unique coincidence detector and an unique network listing for all the event-messages, that are originated by the remote stations and circulated in the whole network.



BOCHUM UNIVERSITY GERMANY, SHORT PERIOD STATION NETWORK

fig. 1

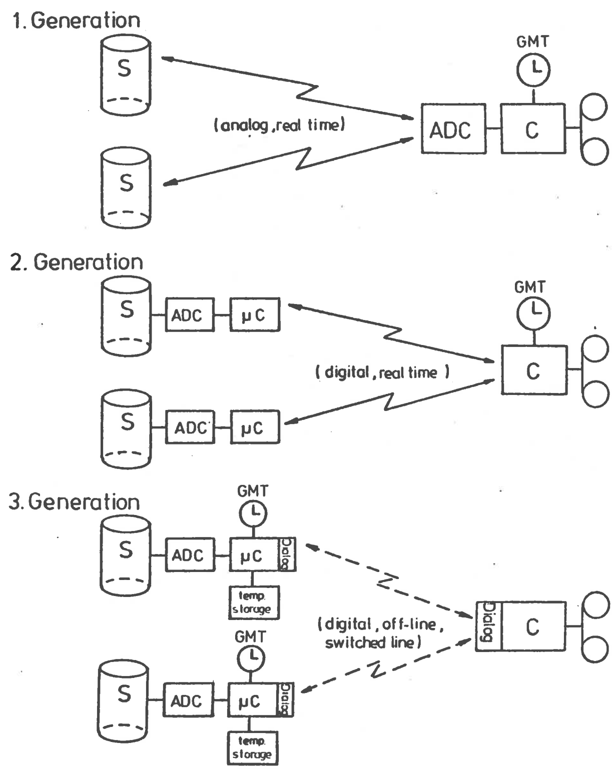
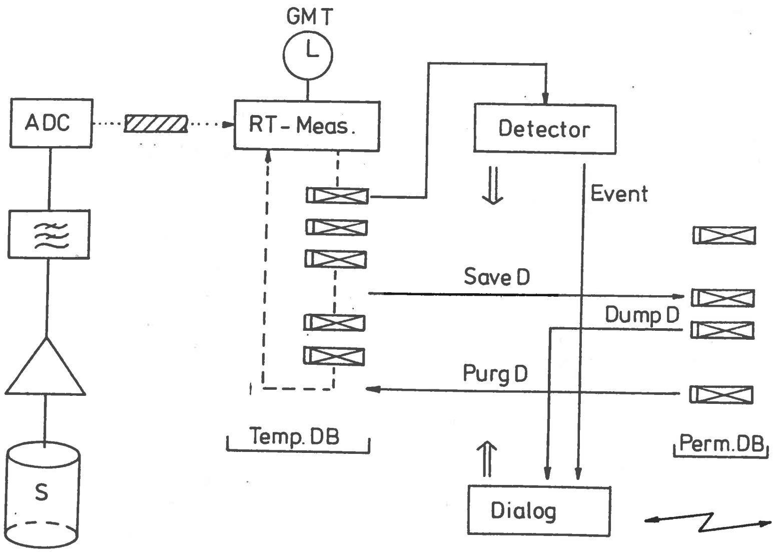


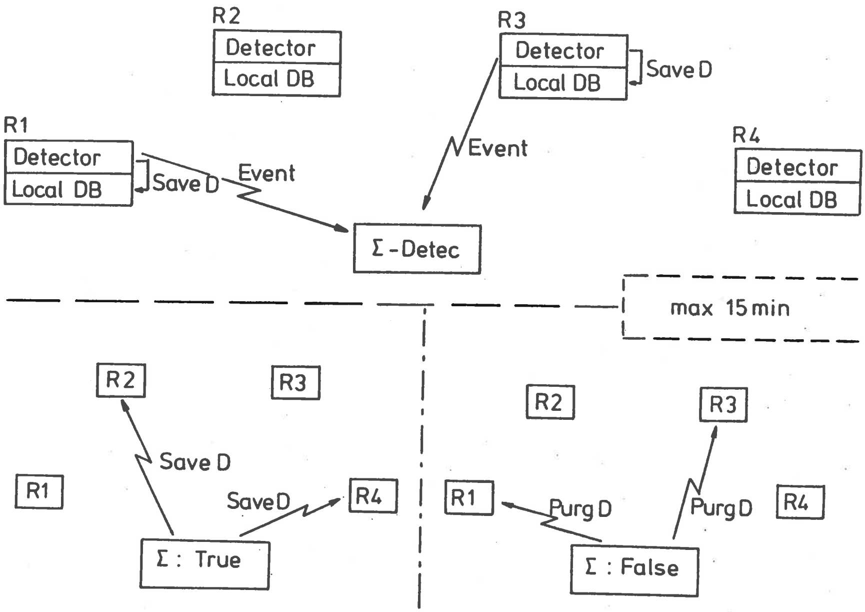
fig. 2

History of Network Architecture



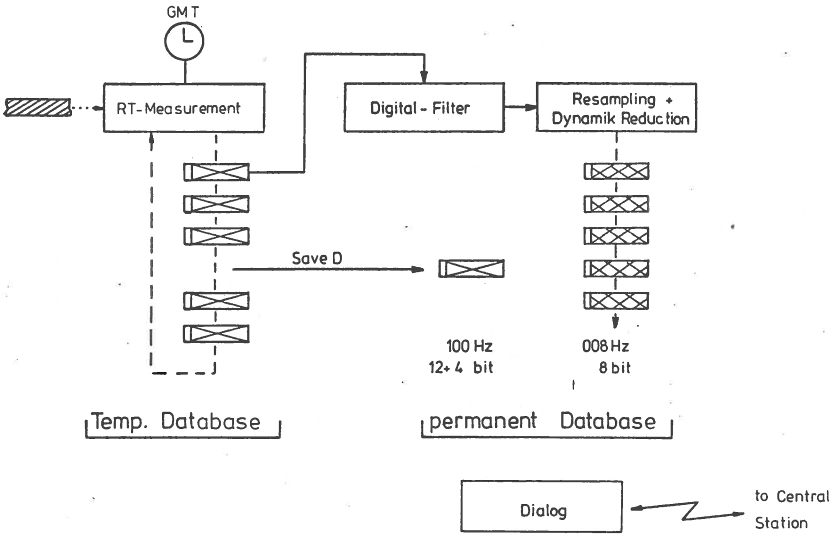
Function of Remote Station

fig. 3



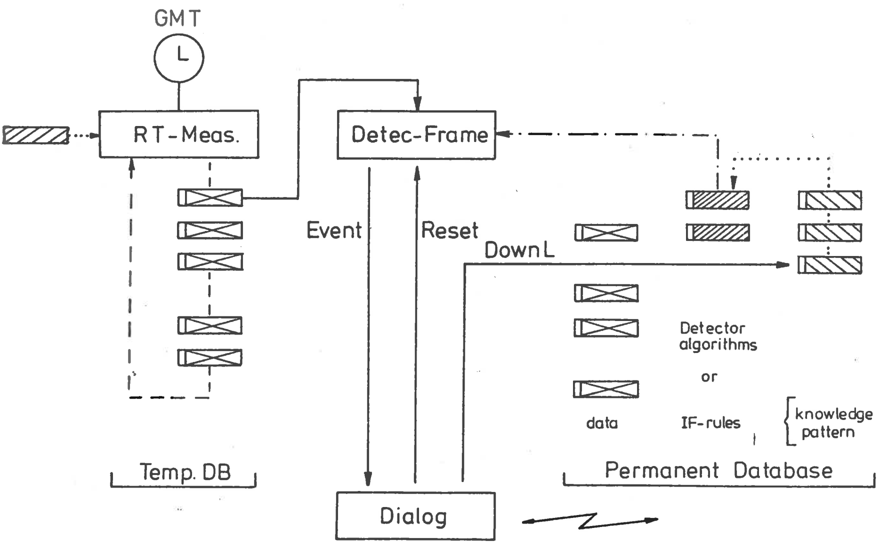
Dialog in Station Network

fig. 4



Different Datatypes in Database of Remote Station

fig. 5



Detectors in Remote Station

fig. 6

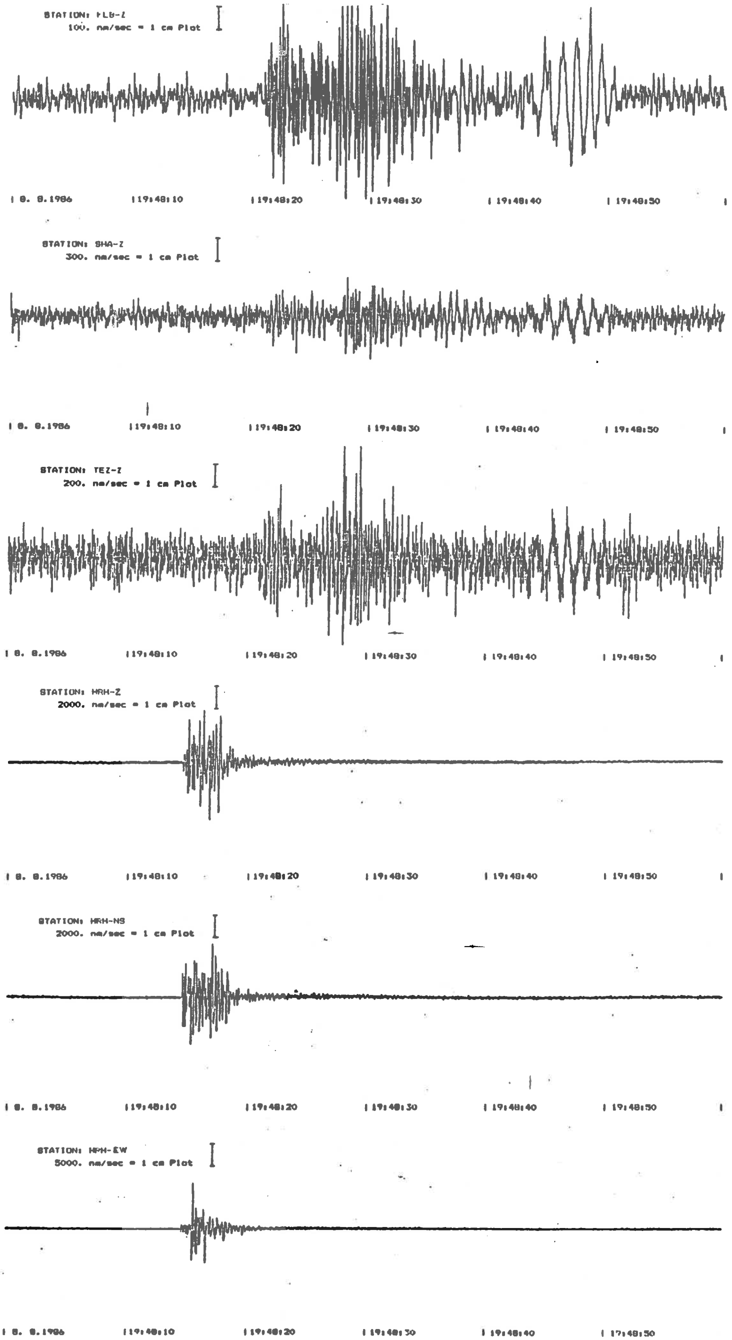
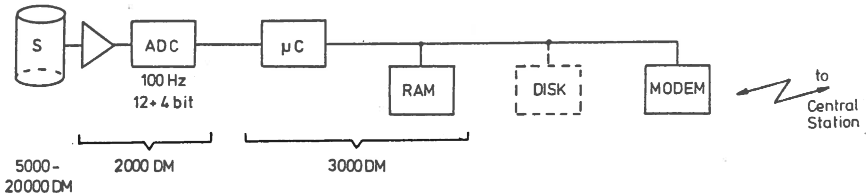

STATION: FLB-Z
100. nm/sec = 1 cm Plot
8. 8.1986
19:48:10
19:48:20
19:48:30
19:48:40
19:48:50
STATION: SHA-Z
300. nm/sec = 1 cm Plot
STATION: TEZ-Z
200. nm/sec = 1 cm Plot
STATION: HRH-Z
2000. nm/sec = 1 cm Plot
STATION: HRH-NS
2000. nm/sec = 1 cm Plot
STATION: HRH-EW
5000. nm/sec = 1 cm Plot

fig. 7


KLB-Z
29.04.1986
24:00
21:00
18:00
15:00
12:00
9:00
6:00
3:00
0:00
1:00
1:01
1:02
1:03
1:04
1:05
bis :30

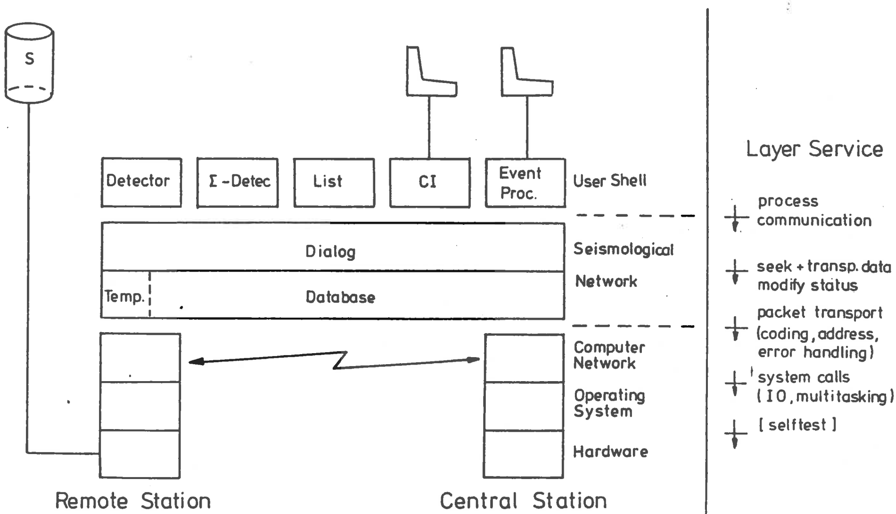
fig. 8



	CPU-time for Walsh-Detector	local storage (solid state) size	7 days storage (disk) costs	data transmission prinziple	data transmission costs
1978	~~200 %~~	2 min	150 000 DM	dedicated line	50km = 70DM/day
1982	20 %	20 min	50 000 DM	switched line	1h 100Hz or 24h 8Hz
1986	5 %	2 h	20 000 DM	(X.25)	= 30 DM
1990	≈ 1 %	≈ 8 h	≈ 5 000 DM	(ISDN)	= 1 DM

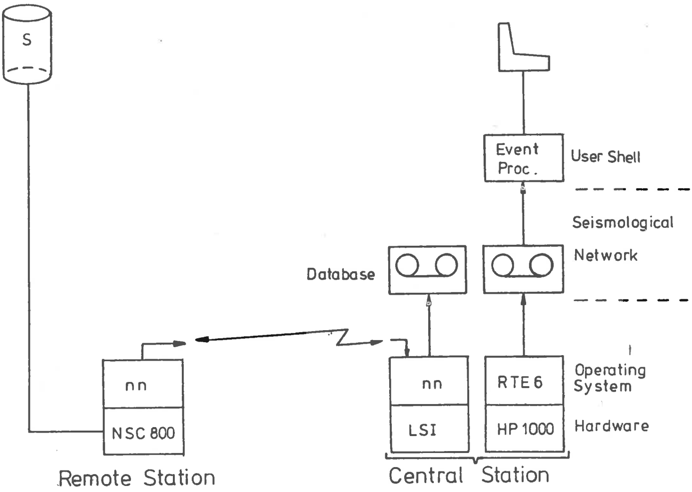
Performance and Costs of a Single Trace Remote Station

fig. 9



System Layers in a Seismological Network

fig. 10



GRF - Array in the Layer Model

fig. 11

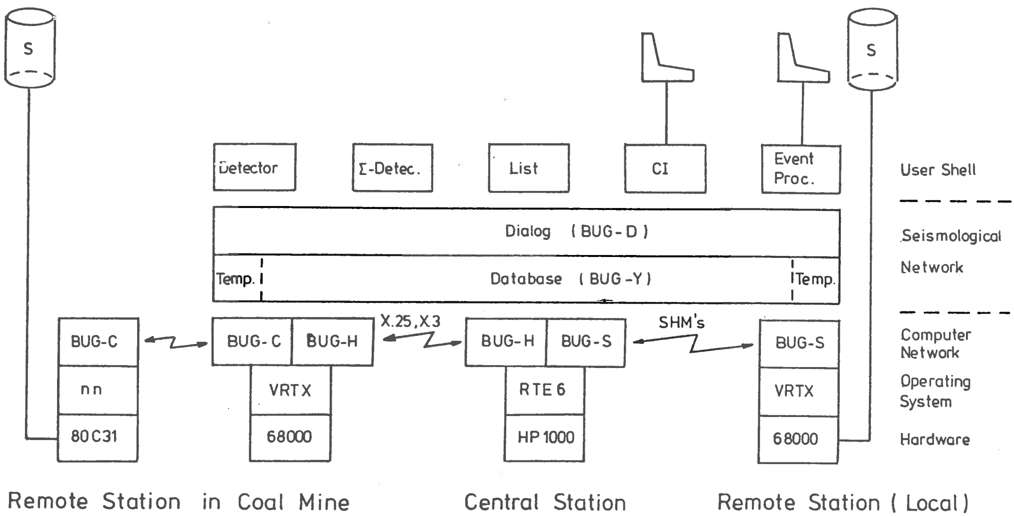


fig. 12

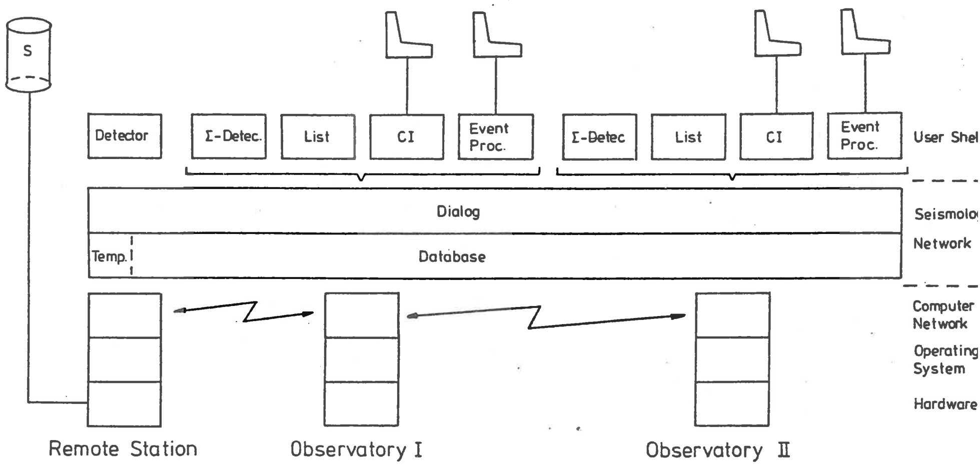
BUG - Network in the Layer Model

```
SaveD_100                                       PlotD_100     DumpD_008   Download
---type 1---//---type 2---//---type 3---        ------filter  ----shift   --------file-


KLS-Z   40/80  KLS-Z   20/60  KLS-Z   20/60  KLS-Z   .5-8.
KLS-NS  40/80  KLS-NS  20/60  KLS-NS  20/60  KLS-NS  .5-8.
KLS-EW  40/80  KLS-EW  20/60  KLS-EW  20/60  KLS-EW  .5-8.
KLB-Z   40/80  KLB-Z   20/60  KLB-Z   20/60  KLB-Z          KLB-Z   02  KLB-Z  WALSH1
SHA-Z   40/80  SHA-Z   20/60  SHA-Z   20/60  SHA-Z   .5-8.              SHA-Z  WALSH1
TEZ-Z   40/80  TEZ-Z   20/60  TEZ-Z   20/60  TEZ-Z   .5-8.              TEZ-Z  WALSH1
NA -Z   40/80  NA -Z   20/60  NA -Z   20/60  NA -Z   .5-4.              NA -Z  SRO1
HRH-Z   40/80  HRH-Z   20/40                 HRH-Z          HRH-Z   01  HRH-Z  WALSH2
HRH-NS  40/80  HRH-NS  20/40                 HRH-NS
HRH-EW  40/80  HRH-EW  20/40                 HRH-EW
RPM-Z   40/80                 RPM-Z   20/40  RPM-Z   .5-8.  RPM-Z   04  RPM-Z  WALSH3
RPM-NS  40/80                 RPM-NS  20/40  RPM-NS  .5-8.  RPM-NS  04
RPM-EW  40/80                 RPM-EW  20/40  RPM-EW  .5-8.  RPM-EW  04
```

Network Listing

fig. 13



Network of Observatories in the Layer Model

fig. 14

EARTHQUAKES WITH A TENSILE SOURCE COMPONENT

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To determine tensile source component in the seismic focus, a procedure based on the construction of radiation pattern is used. From the seismic zones wiht good azimuthal distribtuion of stations in the world seismic network, earthquakes which occurred in the 1971-81 period were analyzed; for these events better agreement of the observed and theoretical patterns was found for combined shear-tensile source mechanism than for the pure double-couple one. The share of the tensile component was always found to be relatively small, ranging from 1 to 13% of the shear component. The comparison of the two solutions (double-couple vs. combined shear-tensile) is based on the first onset signs statistics. The results obtained indicate that tensilefracturing does not play a substantial role in the total amount of released seismic energy; it is expected to be more important in the creation and development of focal zone morphology from the instantaneous and long-term points of view.

PROBLEMS IN CALCULATING SEISMIC WAVE ENERGY FROM TELESEISMIC SIGNALS

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Complementary to the source moment the radiated seismic energy is one of the physically best defined quantities to characterize earthquakes. Its determination by integration of the kinetic ground energy density of P- and S-Signals in the time domain is straight forward. Problems arise with the reduction from teleseismic distances to the source. Anelastic absorption along the path turns out to be the most critical factor. Application of respective corrections in time domain is problematic. Alternatively, by virtue of Parseval´s Theorem, kinetic energy can be calculated in the frequency domain by integration of the power spectrum with the possibility of applying proper corrections even for frequency dependent Q. Sadisfactory Q-models have to meet several conditions:

1. Short period power density spectrum in agreement with seismic source models and near field observations.
2. Conformity with standard Q-models.
3. Energy partition between P and S in agreement with theoretica exspectations and practical observations.

A Q-model $\sim\omega^{\alpha}$ with $0.2 < \alpha < 0.25$ fixed at T = 10 s to the SL2-model of Anderson and Hart leads to satisfactory results.

THE INFLUENCE OF THE LOCAL GEOLOGICAL CONDITIONS ON THE SEISMIC WAVE SPECTRA

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Abstract: In order to study the effects of the local geological conditions on the seismic wave spectra, the Power Spectral Density (PSD) of the P waves generated by some intermediate-depth Vrancea earthquakes was analysed. The PSD was determined in the time domain for 19 events with magnitudes $M_L \geqslant 4$, recorded at four stations from the Romanian telemetered seismic network. The frequencies corresponding to the PSD maxima were determined for all the earthquakes at every station and the mean frequency of the respective maximum, with its standard deviation was computed. Following the idea of a possible correlation between the PSD and the local geological conditions, these frequencies were assimilated with the frequencies corresponding to the maxima of the transfer function of the soil profile under the station. The good correlation between the mean PSD and the theoretical transfer function of the local geology computed by using the Thomson - Haskell method was put into evidence.

INTRODUCTION

In their propagation through the Earth, the seismic body waves generated in an earthquake focus suffer phenomena of refraction, reflexion, diffraction, attenuation and frequency dependent transmission. These influences can radically change the frequency content and the waveforms of the source generated displacement.

In the short period body wave range ($0.1 < T < 1$ s), the wave lengths ($\lambda = v_P T$) are from hundreds of meters to kilometers, which means that the effect of the layers having this order of magnitude thickness becomes important. So, in this period range the local geology at the seismic station begins to have a significant influence on the amplitude and frequency content of the seismic waves.

In order to study the effects of the local geological conditions, the Power Spectral Densities (PSD) of the P waves generated by some intermediate-depth Vrancea earthquakes are analysed.

THE METHOD

From the visual analysis of the seismic recordings (vertical component, velocity, S-13 short period seismograph), it comes out that the duration of the maximum oscillations of the P waves is included in the range o.5-2 seconds (depending on magnitude). The first 5 seconds of the recordings were analysed, considering that the Pcoda waves includes information on the local geology at the station.

Because of the irregular character of the velocity Fourier amplitude spectra, which makes difficult the estimation of the spectral maxima, the Power Spectral Densities (PSD) for a frequency interval of o.5 Hz were determined. The Power Spectral Densities are smoother and without irregularities and allow the determination without ambiguity of the spectral domains corresponding to the maximum of the seismic signal power and so of the predominant periods.

The PSD was determined in the time domain, using the known definition of the signal power, with the relation:

$$PSD(f) = \frac{P(f)}{\Delta f} = \frac{1}{T \cdot \Delta f} \left[\int_0^T s_2^2(t)dt - \int_0^T s_1^2(t)dt \right] \quad (1)$$

where:

PSD(f) - the Power Spectral Density at the frequency f;

T - the signal duration (T = 5 sec);

$\Delta f = f_2 - f_1$ - the frequency interval for computing the power (Δf = o.5 Hz);

$s_1(t)$, $s_2(t)$ - the low-pass filtered seismograms with the cut-off frequency f_1 and f_2 respectively ($f_2 > f_1$).

The low-pass filtering was also made in the time domain, using a Cebîşev filter, with 2o dB/octave attenuation.

The determination of the PSD in the time domain was preferred because the Fast Fourier Transform (FFT) method for current computation of amplitude spectra presents, besides its great rapidity, two drawbacks: the work with constrained durations of the analysed signal (the values number must be a multiple of 2, which determines its length for a given digitization rate), and the fact that for periods close to the signal duration, the spectral amplitudes become unrealistic, because constraint periods (submultiples of the signal duration) are used.

OBSERVATIONAL DATA

Using the described method, the PSD for 4 stations from the telemetered seismic network (Fig.1) were determined, for 19 intermediate-depth Vrancea earthquakes with magnitudes $M_L \geqslant 4$ (Table 1). These stations are equipped with S-13 short period seismographs (vertical component) and telemetered at the recording center in Bucharest.

The seismic data are digitized with a rate of 50 Hz and on-line processed on a PDP 11/34 computer, for the seismic event detection and recording on magnetic tapes.

THE ANALYSIS OF THE RESULTS

The PSD values for the events recorded at the mentioned seismic stations were normalized at the maximum value (because in this study we are interested only in the maxima, not in the absolute values) and are plotted, as a function of frequency (Figs.2 a & 2 b). The PSD analysis for every station and event, surely indicated a PSD similarity, namely the frequencies corresponding to the spectral maxima are almost identical for the earthquakes recorded at a given station. We also notice that, although the frequencies of the maxima are almost common for all the events, the relative values of the corresponding spectral maxima may differ fundamentally from one event to the other, even to the complete disappearance.

The frequencies corresponding to the PSD maxima were determined for all the earthquakes at each station and the mean frequency of the respective maximum, with its standard deviation was computed. The values of these mean frequencies corresponding to the PSD maxima at each station, which offer an image on the local predominant frequencies, are presented in Tables 2 a & 2 b. It comes out that the majority of the events have close maxima in the high frequency domain (4-7 Hz), but some events have maxima also in the low frequency domain (1-3 Hz). The existence of common frequencies for all the events at a given station and the fact that these common frequencies differ from one station to the other, proves that this set of frequencies represents a station characteristic, depending a little on the earthquake.

Following the idea of a possible correlation between the PSD and the local geological conditions (Katz, 1976), these frequencies were assimilated with the frequencies corresponding to the maxima of the transfer function of the soil profile under the station.

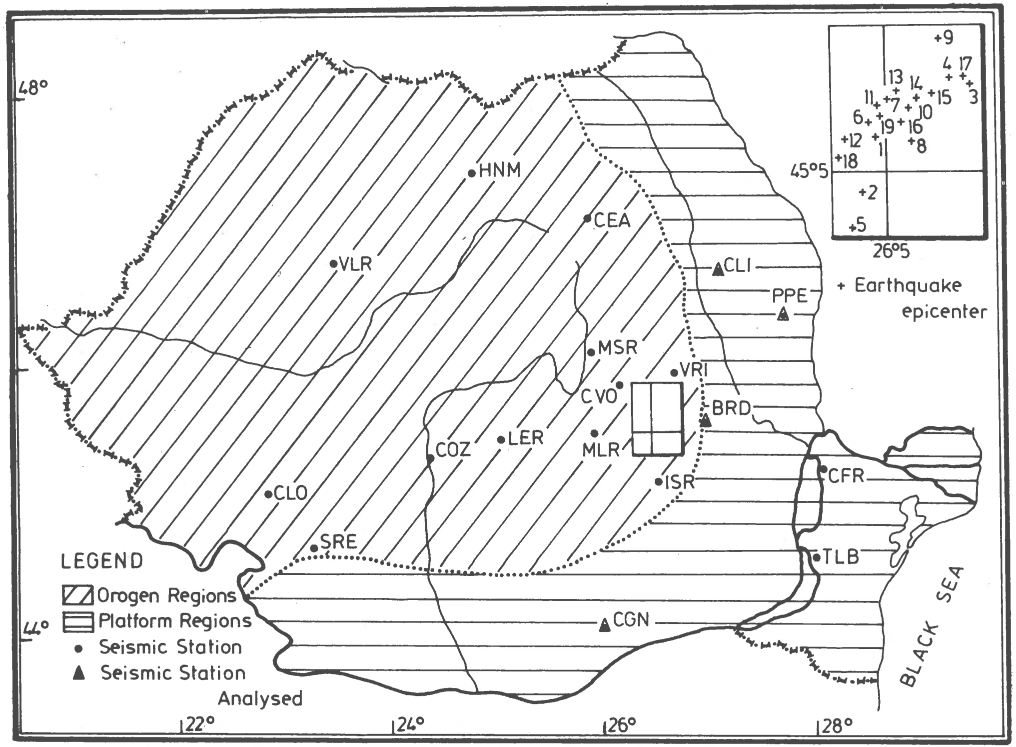


Fig.1 Map showing the Romanian telemetered seismic network and locations of the analysed stations relative to the Vrancea epicentral area.

Table 1
Earthquakes providing data used in this paper

No	Date (y/m/d)	Lat.N	Long.E	h (km)	M_L
1	82o125	45.58	26.47	142	4.2
2	82o3o2	45.45	26.42	114	4.3
3	82o311	45.7o	26.79	113	4.2
4	82o5o6	45.71	26.72	95	4.o
5	82o516	45.37	26.38	2o1	4.3
6	82o6o5	45.62	26.45	157	4.4
7	82o612	45.66	26.51	142	4.o
8	821o16	45.57	26.44	14o	4.6
9	821o18	45.81	26.69	98	4.o
1o	8211o5	45.65	26.58	141	4.6
11	8211o7	45.65	26.49	154	4.4
12	83o3o6	45.57	26.36	146	4.o
13	83o311	45.68	26.54	154	5.o
14	83o412	45.67	26.61	14o	4.8
15	83o424	45.68	26.66	13o	4.o
16	83o521	45.62	26.55	14o	4.5
17	83o6o6	45.72	26.77	128	4.4
18	83o817	45.54	26.34	152	4.5
19	83o825	45.63	26.49	114	4.o

In order to compare the PSD with the theoretical transfer function of the local geology, the mean PSD per station was determined by the arithmetic mediation of the PSD values for all the events recorded at a given station, at each frequency. This mean PSD value was also normalized at the maximum value.

THE ADOPTION OF THE LOCAL GEOLOGICAL MODEL

In order to determine the theoretical transfer function of the site geology using the Thomson-Haskell method, the thickness, the density and the P and S wave velocities in every layer must be known. These data were obtained from geological bore holes carried out by the Entreprise of Geological and Geophysical Surveys, Bucharest. For every seismic station, the nearest bore hole was selected, so that the deep geological structure may be considered as a characteristic of the station site. These data

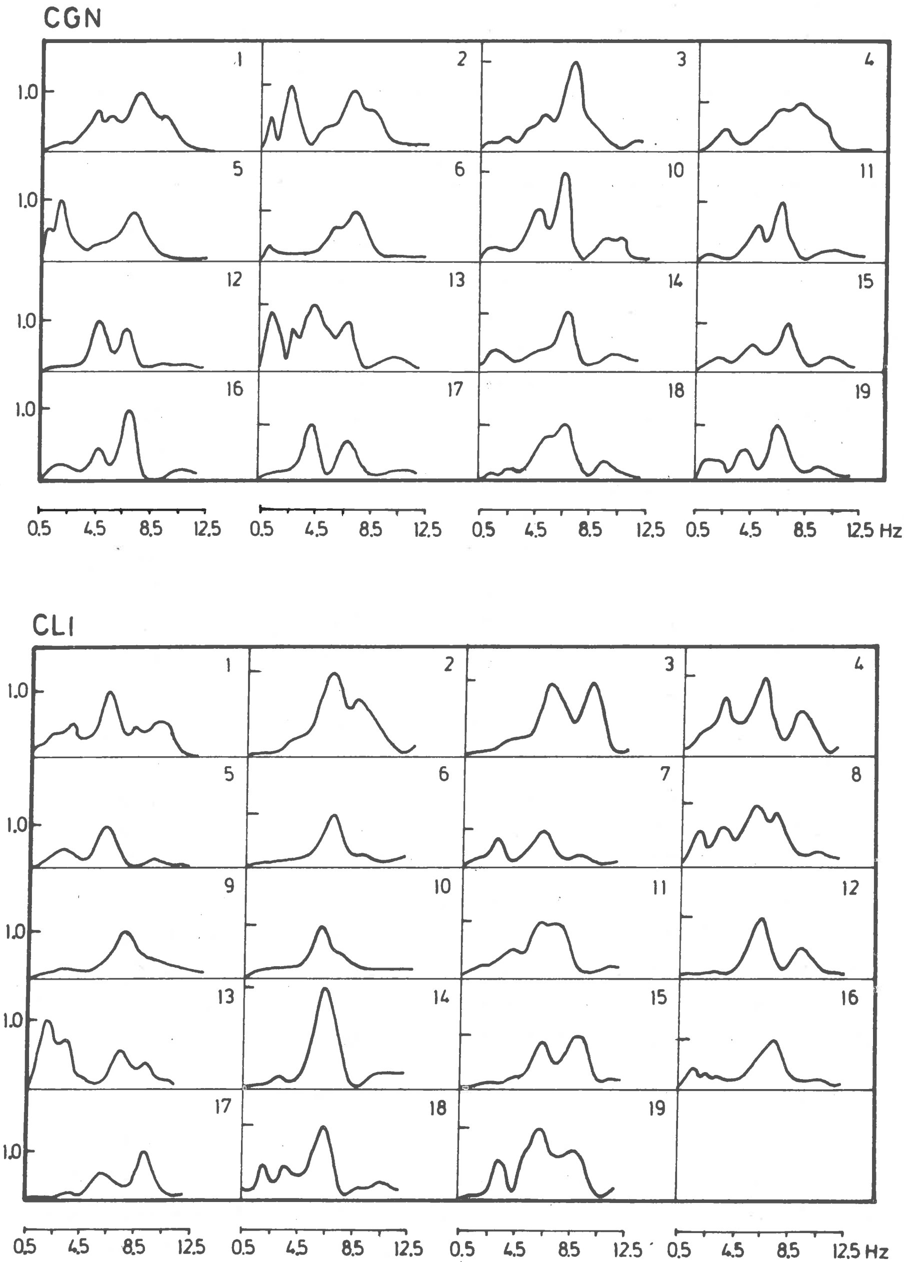


Fig.2a.Power spectral density computed for seismic events recorded at the Călugăreni (CGN) and Coloneşti (CLI) stations.

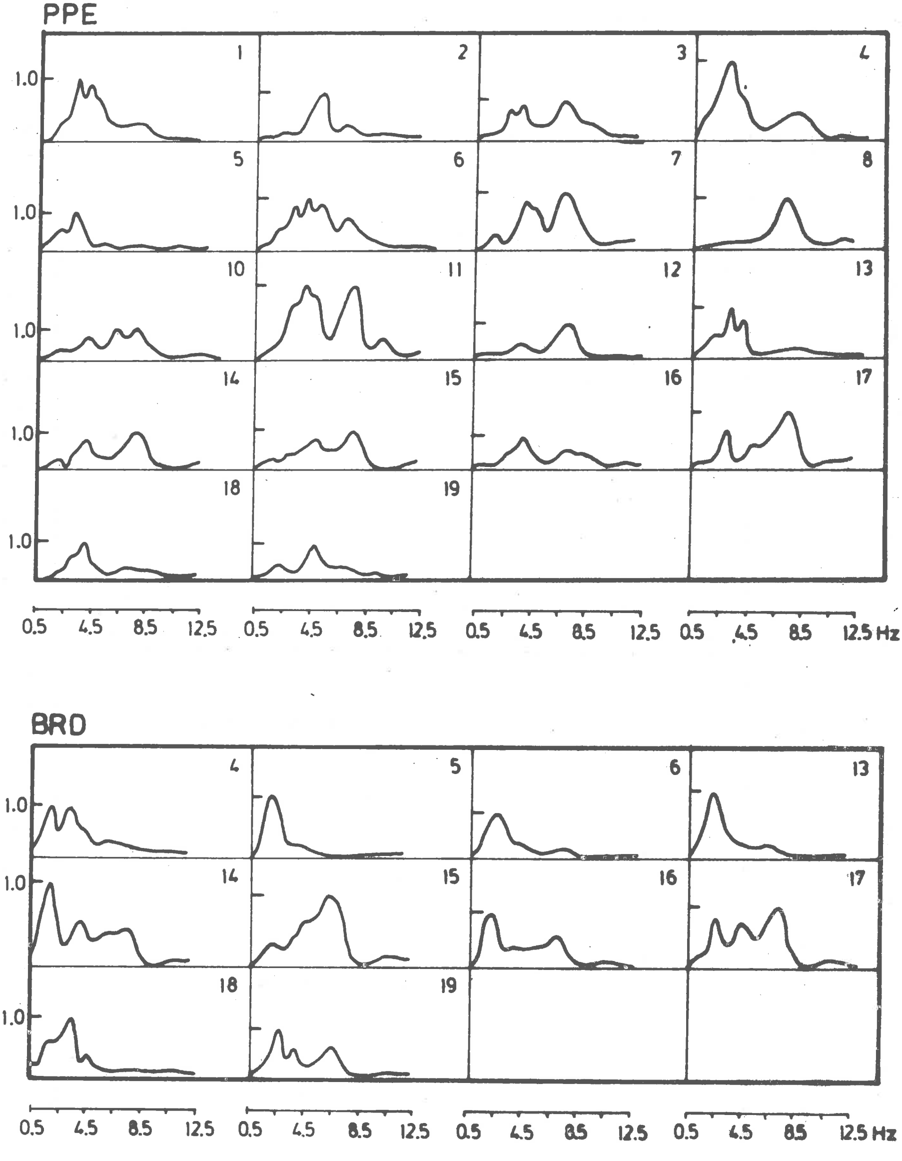


Fig.2b.Power spectral density computed for seismic events recorded at the Popeni (PPE) and Bordeşti (BRD) stations.

Table 2a

Predominant frequencies at the Popeni (PPE) and Colonești (CLI) seismic stations

PPE

No	f_1	f_2	f_3	f_4	f_5
1	-	3.o	4.o	-	7.5
2	-	-	-	5.o	6.7
3	-	3.o	4.o	-	7.o
4	-	3.o	-	-	7.7
5	2.o	3.o	-	-	-
6	-	3.o	4.o	5.o	7.o
7	2.o	-	4.o	-	6.7
8	-	-	-	-	7.2
9	2.3	-	4.o	-	-
1o	2.o	-	4.o	-	7.5
11	-	3.o	4.o	5.o	7.5
12	-	-	4.o	-	7.o
13	2.o	3.o	4.o	-	7.5
14	2.o	-	4.o	-	7.o
15	2.o	3.o	-	5.o	7.5
16	-	-	4.o	-	7.2
17	-	3.o	-	5.o	7.5
18	-	3.o	4.o	-	7.o
19	2.5	-	-	5.o	-
$\bar{f}$	2.1±o.2	3.o±o.o	4.o±o.o	5.o±o.o	7.2±o.3

CLI

No	f_1	f_2	f_3	f_4	f_5
1	-	3.5	6.5	-	1o.o
2	-	-	6.5	8.2	-
3	-	-	6.5	-	9.5
4	-	3.5	6.5	-	9.o
5	-	2.8	6.2	-	9.5
6	-	-	6.8	-	-
7	-	3.3	6.5	-	-
8	2.o	3.5	6.o	7.5	-
9	-	-	-	7.5	-
1o	-	-	6.2	-	-
11	-	-	-	-	-
12	-	-	6.5	-	9.5
13	2.o	3.5	-	7.5	9.o
14	-	-	6.5	-	-
15	-	-	6.5	-	9.o
16	1.5	-	-	7.5	-
17	-	-	6.3	-	9.5
18	2.o	3.5	6.5	-	-
19	-	3.5	6.5	-	9.o
$\bar{f}$	1.9±o.2	3.4±o.2	6.4±o.2	7.6±o.3	9.3±o.3

Table 2b

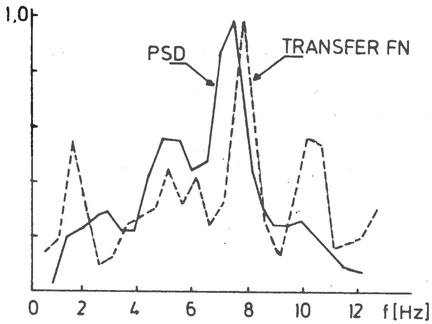
Predominant frequencies at the Călugăreni (CGN) and Bordeşti (BRD) seismic stations

CGN

No	f_1	f_2	f_3	f_4	f_5
1	-	-	4.5	7.5	-
2	1.o	2.5	-	7.o	-
3	-	-	5.o	7.2	-
4	-	2.5	-	8.o	-
5	-	2.2	-	7.2	-
6	1.o	-	-	7.2	-
1o	-	-	5.o	7.o	1o.5
11	-	-	5.o	7.o	-
12	-	-	4.8	7.o	-
13	1.5	3.o	4.5	7.o	1o.o
14	1.5	-	-	7.o	-
15	-	2.5	4.5	7.o	1o.5
16	1.5	-	4.7	7.o	1o.5
17	-	-	4.5	7.o	1o.5
18	1.5	2.5	-	7.o	1o.o
19	1.5	2.5	4.o	6.7	9.5
$\bar{f}$	1.4±o.2	2.5±o.2	4.6±o3	7.o±o.2	1o.2±o.4

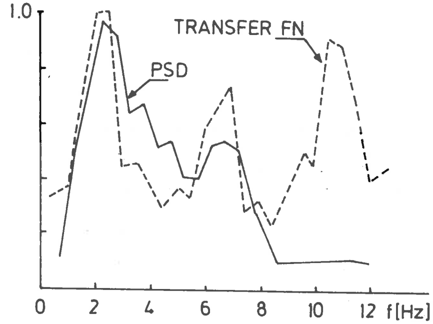
BRD

No	f_1	f_2	f_3	f_4
4	2.o	3.5	-	6.o
5	2.o	-	-	-
6	2.2	-	-	-
7	2.o	3.5	4.5	6.o
8	2.o	3.5	5.2	-
9	2.o	-	4.5	7.o
13	2.2	-	-	6.o
14	2.o	-	4.2	7.5
15	2.o	-	4.5	6.3
16	2.o	3.5	-	6.5
17	2.5	-	4.5	7.o
18	2.o	3.5	4.5	-
19	2.5	3.5	-	6.3
$\bar{f}$	2.1±o.2	3.5±o.o	4.5±o.3	6.5±o.5



CGN

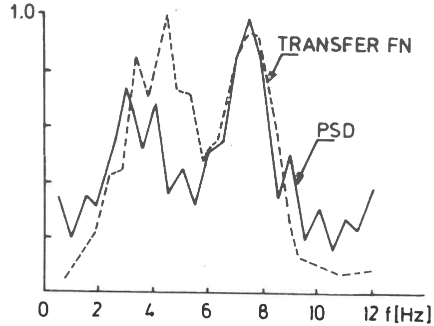
GEOLOGICAL SECTION	AGE	THICKNESS (m)	VELOCITY P m/sec	DENSITY ρ
LOESS LIKE DEP. SAND CLAY	Q	60	800	1.8
SANDS & GRAVEL	Pl	250	1800	2.2
LIMESTONE	K	1150	5500	2,5
MARL CLAY	J	1120	3500	2.3
SANDSTONE DOLOMITE	T	–	5600	2,5



BRD

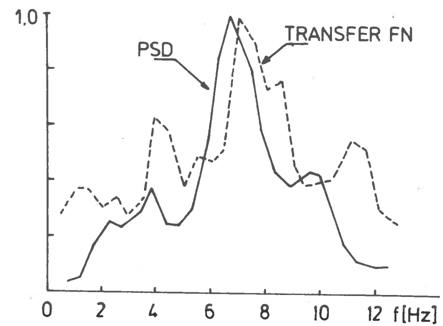
GEOLOGICAL SECTION	AGE	THICKNESS (m)	VELOCITY P m/sec	DENSITY ρ
LOESS-LIKE DEP. SAND CLAY	Q/lv	115	1000	1.9
CLAY	lv/d	2000	2650	2.2
SAND CLAY	p/me	3350	3550	2,5
SAND	sm	2400	4000	2,5
CLAY		–	5500	2,6

Fig.3 a Diagrams showing the comparison between the theoretical transfer function and the observed mean PSD at the Călugăreni (CGN) and Bordeşti (BRD) stations



PPE

GEOLOGICAL SECTION	AGE	THICKNESS (m)	VELOCITY P m/sec	DENSITY ρ
LOESS-LIKE DEP. SAND	Q+lv	95	1000	1,8
CLAY	p+dc	595	2300	2,2
MARL SANDSTONE	sm	370		2,3
LIMESTONE MARL	to	354	3280	2,6
SANDSTONE LIMESTONE	Pz	-	5500	2,7



CLI

GEOLOGICAL SECTION	AGE	THICKNESS (m)	VELOCITY P m/sec	DENSITY ρ
LOESS-LIKE DEP. SAND CLAY	Q/me	40	1200	1.9
MARL SANSTONE	sm	680	2300	2,4
LIMESTONE		1600	3000	2,5
SANDSTONE	to	600	5250	2,7
LIMESTONE	K			
SANDSTONE	J			
		-	6250	2,7

Fig.3 b Diagrams showing the comparison between the theoretical transfer function and the observed mean PSD at the Popeni (PPE) and Colonești (CLI) stations

were completed (especially for the first hundreds meters from the surface) with data contained in geological maps and reports on the analysed region and in some occasions, with the results of own geological and geophysical studies (Mândrescu, 1966; Mândrescu, 1969).

The theoretical transfer functions have been computed for PV waves using the Thomson-Haskell method, for a mean incidence angle at every station, estimated for 12o km depth.

As we may notice, a good correlation exists between the theoretical transfer function and the observed mean PSD at every analysed station (Figs. 3 a & 3 b).

CONSLUSIONS

The analysis of spectra of the seismic waves recorded at the Bordeşti, Călugăreni, Coloneşti and Popeni stations, puts into evidence the following aspects:

- the existence of spectral characteristics common for all the seismic events recorded at a station, but different from one station to the other;

-the existence of some maxima at frequencies lower than 2 Hz, which are strongly excited by large Vrancea intermediate - depth earthquakes;

- the good correlation between the mean PSD and the theoretical transfer functions, which puts into evidence the decisive influence of the local geological conditions on the recorded seismic waves.

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INVESTIGATION OF MACROSEISMIC DATA OF STRONG EARTHQUAKES IN WESTERN BOHEMIA IN DECEMBER 1985 AND JANUARY 1986

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Summary: The region 50.0 - 50.4° N, 12.0 - 12.6° E is characterized by the earthquake swarms. The people have again observed single shocks by help of sound effects since the beginning of the year 1985. A lot of shocks were felt macroseismically in December 1985 and in the beginning of the year 1986. The paper includes the description of these data, their evaluation and properties of macroseismic fields.

The region Aš-Selb-Skalná-Kraslice-Markneukirchen-Bad Brambach, Fig.1, determined by the co-ordinates φ = 50 - 50.4° N, λ = 12 - 12.6° E is characterized by earthquake swarms /1/. It is the region on the crossing of the Krušné hory Mts fault with the Mariánské Lázně and the Tachov faults. It is lying between the deep-seated faults of Jáchymov, Litoměřice and Central Saxony. Documents about shocks in this region have been available since the year 1198.

In the epicentral area people have again observed single shocks by help of sound effects since the beginning of the year 1985. A lot of shocks (about one thousand) were observed macroseismically in December 1985 and in January 1986. Fig. 2 shows the daily numbers of shocks N recorded macroseismically in the interval November 26, 1985 to April 7, 1986. Its analysis shows that the earthquake swarm consist of several periods of increased activity with a marked decrease between them. Active periods lasted 3 - 6 days, during which as many as hundreds of shocks occurred a day, and they concentrated a round the strongest swarm shocks. This agrees with the results obtained for other earthquake swarms in this region /1, 2/.

The Geophysical Institute of the Czechoslovak Academy of Sciences in Prague collected together 15 292 positive reports from people of Czechoslovakia. The University in Munich collected about 780 positive reports from people of the FRG. The Central Institue of Meteorology and Geodynamics in Vienna collected 23 positive and 34 negative reports from the territory of Austria; at this it is predominantly a matter of collective reports by rural police stations which are the basis of mean representative intensities of the pertinent scope of authority.

The weakest shocks were only manifest by sound effects, stronger ones also by swaying motions and the strongest even by material damage. The greatest material damage in epicentral area: small cracks in walls, fall of fairly large pieces of plaster, cracks in chimneys, parts of chimneys fall down, were caused by the earthquake of Dec. 21, 1985 at 11.16 a.m. CET and by the one of Jan. 21, 1986 at 0.38 a.m. CET /3/.

For the first earthquake the Geophysical Institute of the Czechoslovak Academy of Sciences in Prague collected 6 107 positive reports from people from 497 localities. The University in Munich collected about 210 positive reports from people from about 120 localities. The Central Institute of Meteorology and Geodynamics in Vienna collected 23 positive and 34 negative reports from the territory of Austria. On the basis of these macroseismic data the isoseismal map, Fig. 3, was compiled. It was possible to construct the isoseismals of 6.5°, 6, 5, ..., 3.5° MSK-64.

The macroseismic co-ordinates of the epicentre,

$$\varphi = 50.14^\circ \text{ N}, \ \lambda = 12.44^\circ \text{ E},$$

are identical with the co-ordinates of the centre of gravity of the 6.5° - and 6° - isoseismals. The epicentral intensity,

$$I_o = 7^\circ \text{ MSK-64},$$

corresponds to the maximum macroseismic effects and to the extrapolation of the intensity-distance curve. The macroseismic focal depth,

$$h = 10 \text{ km},$$

was determined by using the Kövesligethy formula as well as the Blake formula and the radii near-field values only ($\alpha = 0.001$, $k = 3$). The macroseismic magnitude,

$$M_m = 4.8,$$

was calculated by using the empirical formula for the Bohemian Massif $M = 0.63\ I_o + 0.5$.

For the earthquake of Jan. 21, 1986 at 0h 38m CET the Geophysical Institute of the Czechoslovak Academy of Sciences in Prague collected 2 431 positive reports from people from 244 localities. The University in Munich collected about 170 positive reports from people from about 75 localities. On the basis of these macroseismic data the isoseismal map, demonstrated on Fig. 4, was compiled. It was possible to construct the isoseismals of 6, 5.5, 5, ... 3.5° MSK-64.

The macroseismic co-ordinates of the epicentre,

$\varphi = 50.27°$ N, $\lambda = 12.42°$ E,

are idential with the co-ordinates of the centre of gravity of the 6° - isoseismal. The epicentral intensity,

$I_o = 6.5°$ MSK-64,

corresponds to the maximum macroseismic effects and to the extrapolation of the intensity-distance curve ($\alpha = 0.001$, $k = 3$). The macroseismic focal depth,

$h = 10$ km,

was determined by using the Kövesligethy formula as well as the Blake formula and the radii near-field values only. The macroseismic magnitude,

$M_m = 4.6$,

was also calculated by using the given empirical formula.

The demonstrated macroseismic fields are not the same in the epicentral area. It is necessary to say that these differences were also observed in the case of last earthquake swarms in this region /1/.

Table 1 shows the comparison of the numerical values of the microseismic and the macroseismic focal parameters for both earthquakes. The differences in the numerical values of parameters determinated by the different sources are smaller for the earthquake of Dec. 21. The near values determined as a centre of gravity are:

for 21.12.1985 50.185° N 12.460° E

and for 20.1.1986 50.220° N 12.435° E.

It shows the epicentre shift to NW.

To investigate the described swarm in detail, several local seismological stations were installed in December 1985. Fig. 5

shows the typical seismogram of the earthquake of Dec. 22, at 06h 23m UTC recorded by the Vegik seismograph (vertical component) located in Oloví. More detailed results concerning this swarm will be presented at the special workshop which will be organized in Mariánské Lázně in December 1986 /5/.

Table 1.

21.12.1985 11h 16m CET	NOAA	ZIPE	GFÚ /4/	macro	EMSC
H/UTC/	10 16 19.01	10 16	10 16 19.32	-	10 16 21.3
φ /°N/	50.173	50.231	50.23	50.14	50.27
λ /°E/	12.409	12.496	12.5	12.44	12.43
h/km/	10	-	-	10	10
M	5.1(GRF)	4.6	4.9	4.8	

21.1.1986 0h 38m CET	NOAA	ZIPE	GFÚ	macro	EMSC
H/UTC/	23 38 28.5	23 38	21 38 28.6	-	23 38 31.4
φ /°N/	50.187	50.197	50.240	50.27	50.24
λ /°E/	12.372	12.509	12.466	12.42	12.45
h/km/	10	-	-	10	10
M	4.9(VKA)	4.2	4.2	4.6	

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/5/ Proceedings of Workshop on Earthquake Swarm in Western Bohemia, Geoph.Inst.Czechosl.Acad.Sci., will be published.

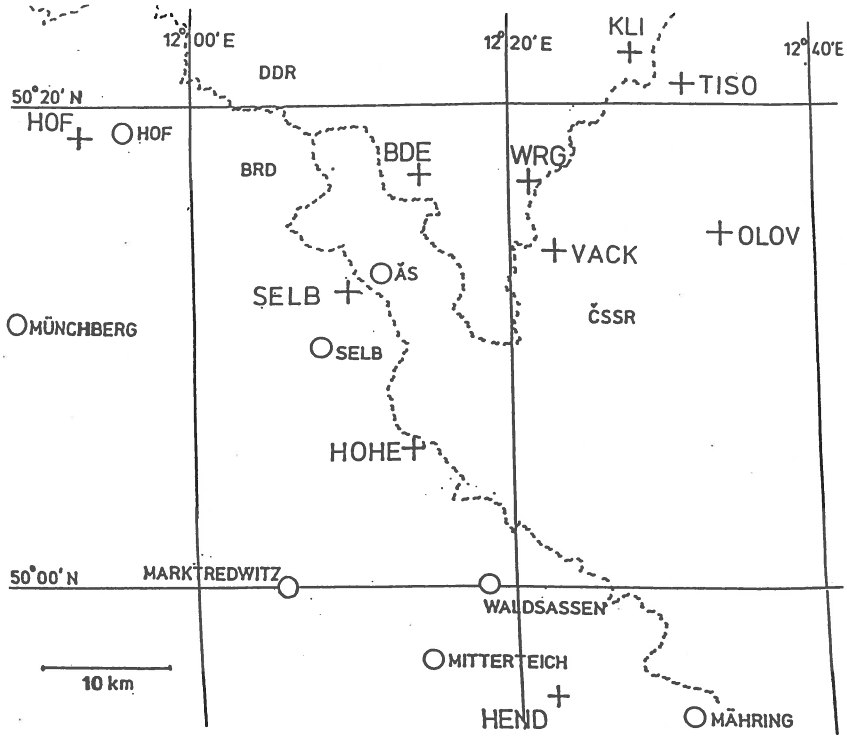

Fig. 1. The region under investigation; cross demote the seismographic station which recorded during the earthquake swarm.

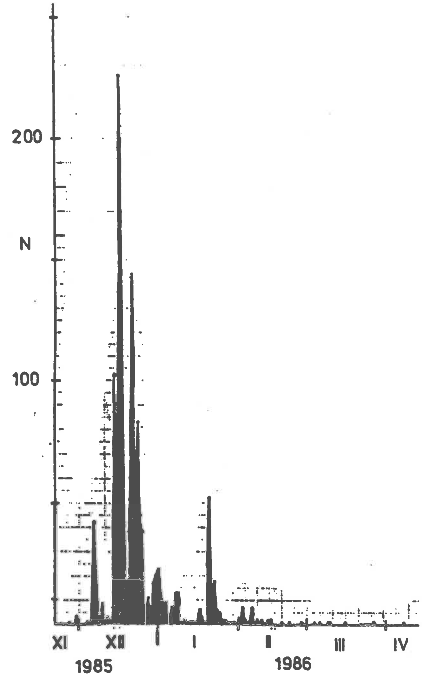

Fig. 2. The daily numbers of shocks N recorded macroseismically vs. time (Nov. 1985 - Apr. 1986).

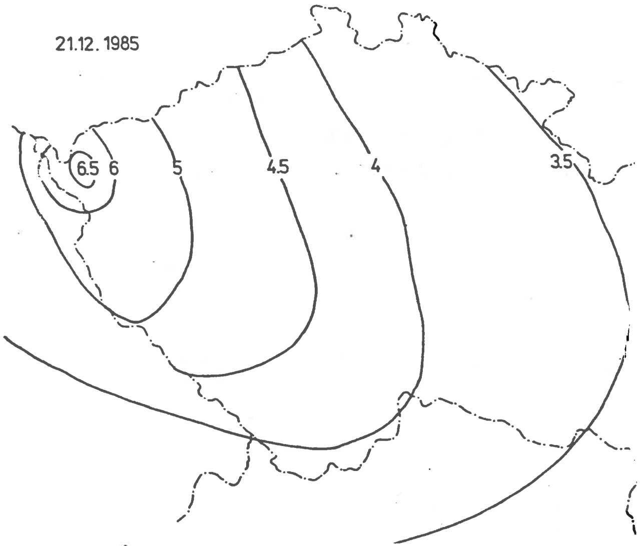

Fig. 3. The isoseismal map of earthquake of Dec. 21, 1985, 10h 16m UTC.

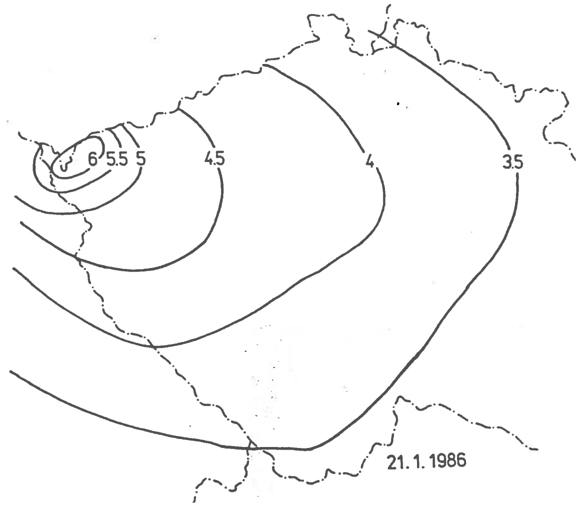

Fig. 4. The isoseismal map of earthquake of Jan. 20, 1986, 23h 38m UTC.

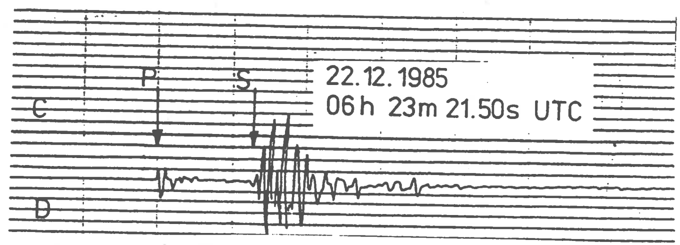

Fig. 5. Seismogram of the earthquake of Dec. 22, 1985 at 06h 23m UTC recorded in seismographic station Oloví.

PROPERTIES OF EARTHQUAKES IN THE MUR-MÜRZ-LEITHA-LITTLE CARPATHIANS REGION

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Summary: From a point of view of the recent seismic activity, a mutual relationship of the region Mur-Mürz-Leitha (a developing hidden deep-seated fault) and the Little Carpathians (deep-seated boundary of the Bohemian Massif and the Slovakian block, the deep-seated Zahorie-Humenné fault) is indicated by comparable focal depths, comparable values of the coefficient of intensity attenuation, the same group of shocks, the connection of time regimes including the space-time tendencies in the occurrence of strong earthquake foci.

The data /1 - 11/ on earthquakes in the region of Mur-Mürz-Leitha and the Little Carpathians, which were studied separately, form comprehensive sets that allow the statistical properties of earthquakes and earthquake regimes to be determined. In assessing the dynamics of the process of earthquake occurrence, we have to analyze historical earthquakes as well. For this reason it is not sufficient to use instrumental data only but it is necessary to consider also macroseismic data.

Fig. 1 shows the earthquake foci with $I_o \geq 6^o$ MSK-64 from the period of 1201 - 1983 on the territory of Austria. A comparison of the space-and-time distribution of the earthquake foci, of the isoseismals in the nearby zone and of the earthquake mechanisms reveals a connection of many earthquakes with the Mur-Mürz-Leitha line /12/. In terms of the works /13, 14/ this line is regarded as a manifestation of a developing hidden deep-seated fault. The epicentre intensity of the strongest earthquake in region Murau on May 5, 1201 was 9^o MSK-64 /5/. In the years 1201 - 1983, 5 earthquakes with $I_o \geq 8^o$ MSK-64 and 21 earthquakes with $I_o \geq 7^o$ MSK-64 were recorded in the study region. The earthquake foci lie in the upper part of the Earth´s crust. Focus depths of 5 - 18km and a typical focus depth of 7km ($\hat{h}$ = 7km) were computed /15/.

In the study region there are two kinds of aftershocks, the examples of which are given in the table 1:

1. Groups of aftershocks (majority), in which the strongest aftershock follows the main shock within several hours.
2. Groups of aftershocks, in which the strongest aftershock does not follow the main shock until after several days and is relatively weak with respect to the strongest aftershock, which in the former case is observed under the same magnitude of the main shock. Due to the fact that both types of aftershocks occur in the same places (e.g. Semmering, Wiener Neustadt), it cannot be accounted for by the structure of the region. The results of the study of focus parameters (stress drop vs. number of aftershocks e.g. for the Friuli region in 1976 /16/ indicate the existence of focus processes of a different character (sometimes small stress drop and sometimes great stress drop) in one focal region in different time intervals that are responsible for the different character of aftershocks (e.g. sometimes a relatively high number of aftershocks, sometimes a relatively low number). It will be possible to verify the hypothesis on a large scale when all the world seismological centres give in all earthquakes in addition to the magnitude also the seismic moment, the stress drop and the focus dimensions. For my part, I intercede for the introduction of such a practice in the next future.

Fig. 2 demonstrates earthquake foci in Slovakia from about 1500 to 1983. The elongation of isoseismals in the near zone shows that the foci are usually connected with the deep-seated boundary of the Bohemian Massif and the Slovak block /12/. Geodetic measurements made on the contact of the Carpathians and the Bohemian Massif are indicative of the existence of tectonic movements in this region even at the present time. The earthquakes are mostly connected with the movements along the Záhorie-Humenné deep-seated fault, which by its direction and position is a continuation of the Mur-Mürz-Leitha line mentioned above. Some earthquakes are also connected with the Dobrá Voda fault; as a matter of fact, in the Dobrá Voda region earthquake foci lie on the intersection of the Záhorie-Humenné deep-seated fault with the Dobrá Voda fault, which belongs to the fault system running from the Nesvačily throug as far as Jablonica in the northeast margin of the Little Carpathians /12, 15/. The southernmore region of Stupava, Pernek, Modra also characterized by an increased number of shocks in the recent time lies on a fault intersection too, it is the intersection of the Záhorie-Humenné fault and a fault parallel to the Dobrá Voda Fault and the Danube fault /12/. The focal depths vary in a range of 4 - 12km, the typical depth being 8km /15/.

The epicentre intensity of the strongest known earthquake of Jan. 9, 1906 in the Dobrá Voda region was $I_o = 8.5^o$ MSK-64. In the last four hundred years reports are available on 8 earthquakes with $I_o \geq 7^o$ MSK-64. An analysis of the data obtained after the year 1700 shows that in this region an earthquake with epicentre intensity $I_o \geq 6^o$ MSK-64 occurs every 50 years. In the 20th century the Dobrá Voda region has been more active than the ambient focal region of Stupava, Pernek, Modra.

Fig. 3 gives the total annual seismic energy released in the period 1800 - 1983. We can see two peaks, one in 1906 and the other in 1930. The years 1890 - 1906 marked the highest activity while the greates amount of seismic energy was released in the years 1904 - 1906. From a long-range point of view, a local increase of seismic activity appeared in the years 1964 - 1967 when only two stronger earthquakes with intensities 6 and 6.5^o MSK-64 occurred. Now we are going to make a comparison of the two regions under discussion.

In the figure 4 we can see Benioff graphs for the Mur-Mürz--Leitha region. (Nos. 40 and 42). Unless we include in the study region the earthquake foci in region Villach, i.e. particularly the strong earthquakes of 1348 and 1690, we shall find that the study-region has been active approximately since the beginning of the 18th century. In order to establish the space-and-time tendencies in earthquake occurrence, we divided the region into several partial regions. In the figure we can see Benioff graphs for regions Murau-Strassburg - No.45, Strassburg-Judenburg - No.38, Leoben-Wiener Neustadt - No. 46, for the region of Schwadorf - No. 39 and of the Little Carpathians - No. 13. If we again eliminate the 1348 and 1690 earthquakes in the Villach region (they are connected with the earthquake regime in north Italy), and if we compare Benioff graphs, we can see that the most active part of the study region is the section Leoben-Wiener Neustadt. It is also evident that active periods do not take place simultaneously and as a rule their character is not identical. For instance, the year 1876 marked the beginning of an active period in region Leoben, Wiener Neustadt (concentrated about the strong shock near Kindberg with $I_o = 8^o$ MSK-64), the year 1885 marked the beginning of an active period in region Schwadorf, and the year 1890 was the beginning of an active period in the region of the Little Carpathians as shown in Fig.4. This fact indicates a space-and-time tendency in strong earthquake occurrence SW → NE.

In regions Mur-Mürz-Leitha and the Little Carpathians we observed:

- a comparable focal depths: Mur-Mürz-Leitha $\hat{h}$ = 7km, the Little Carpathians $\hat{h}$ = 8km;
- comparable values of the coefficient of intensity attenuation in the near zone (Mur-Mürz-Leitha: 0.046, the Little Carpathians: 0.042);
- identical shock groups;
- a follow-up of time regimes including the same space-and-time tendencies in the occurrence of strong earthquake foci (SW → NE).

These fact suggest a mutual connection of both the regions mentioned and point to the necessity of defining focal regions on the basis of a study of the earthquake regime over a long period of time. The application of laboratory results to the observed difference in the numerical values of the parameters from the empirical relation between the number of earthquakes and the epicentre intensity (1901 - 1980 Mur-Mürz-Leitha: e_2 = 5.28, f_2 = = 0.62, correlation coefficient r = -0.994, 1881 - 1983 the Little Carpathians: e_2 = 3.21, f_2 = 0.36, r =-0.989) shows that in the region of the Little Carpathians the stresses are greater than in the Mur-Mürz-Leitha region.

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Table 1.
Aftershocks in the Mur, Mürz, Leitha Region

1. Shock groups, in which the strongest aftershock follows the main shock within a few hours (up to 1 day), e.g.
   Dec.2, 1963 (Wiener Neustadt), I_o = 6.5, ΔI = 2.5, Δt = 4 h
   June 30, 1964 (Semmering), I_o = 5.5, ΔI = 2, Δt = 1/2 d
   June 2, 1969 (Murau), I_o = 6, ΔI = 1, Δt = 2.5 h
   Apr.16, 1972 (Wiener Neustadt), I_o = 7 3/4, ΔI = 1 1/4, Δt = 1 h
   Jan.14, 1978 (Semmering), I_o = 5, ΔI = 1, Δt = 1/2 d
   Apr.14, 1983 (Scheibbs), I_o = 6.5, ΔI = 2, Δt = 3 h

2. Shock groups, in which the strongest aftershock follows the main shock only after a few days, e.g.
   Oct.27, 1964 (Semmering), I_o = 6 3/4, ΔI = 2, Δt = 27 h
   Jan.5, 1972 (Wiener Neustadt), I_o = 6, ΔI = 1, Δt = 3 d
   Aug.6, 1978 (Semmering), I_o = 5, ΔI = 1, Δt = 7 d

I_o - the intensity of the main shock - /° MSK-64/
ΔI= I_o (main shock) - I_o (strongest aftershock) - /° MSK-64/
Δt- the difference in the origin time of the strongest aftershock and the origin time of the main shock
h - hour
d - day

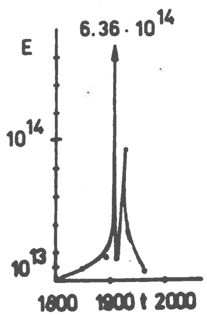

Fig. 3. The total anual seismic energy E /J/ vs.time t in the Little Carpathians in the period 1800 - 1983.

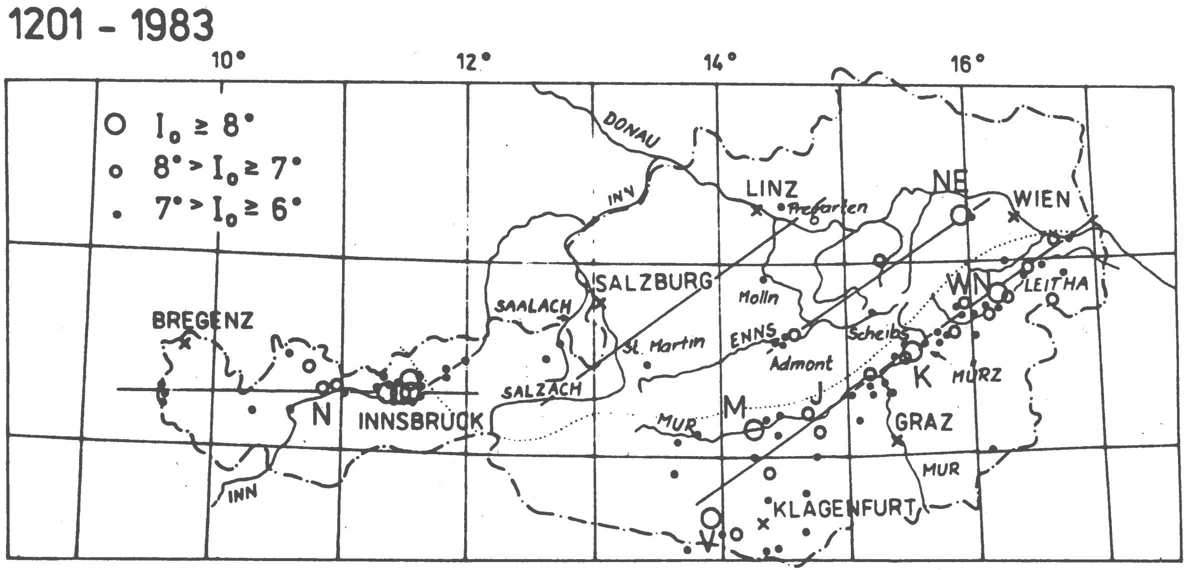

Fig. 1. Earthquake epicentres in Austria, $I_0 \geq 6^0$ MSK-64, time period 1201 - 1983. Explanations: full line - main seismoactive faults, dott line - the boundary between epicentral and remote zones in the macroseismic fields of earthquakes.
N - Namlos, V - Villach, M - Murau, J - Judenburg, K - - Kindberg, WN - Wiener Neustadt, NE - Neulengbach.

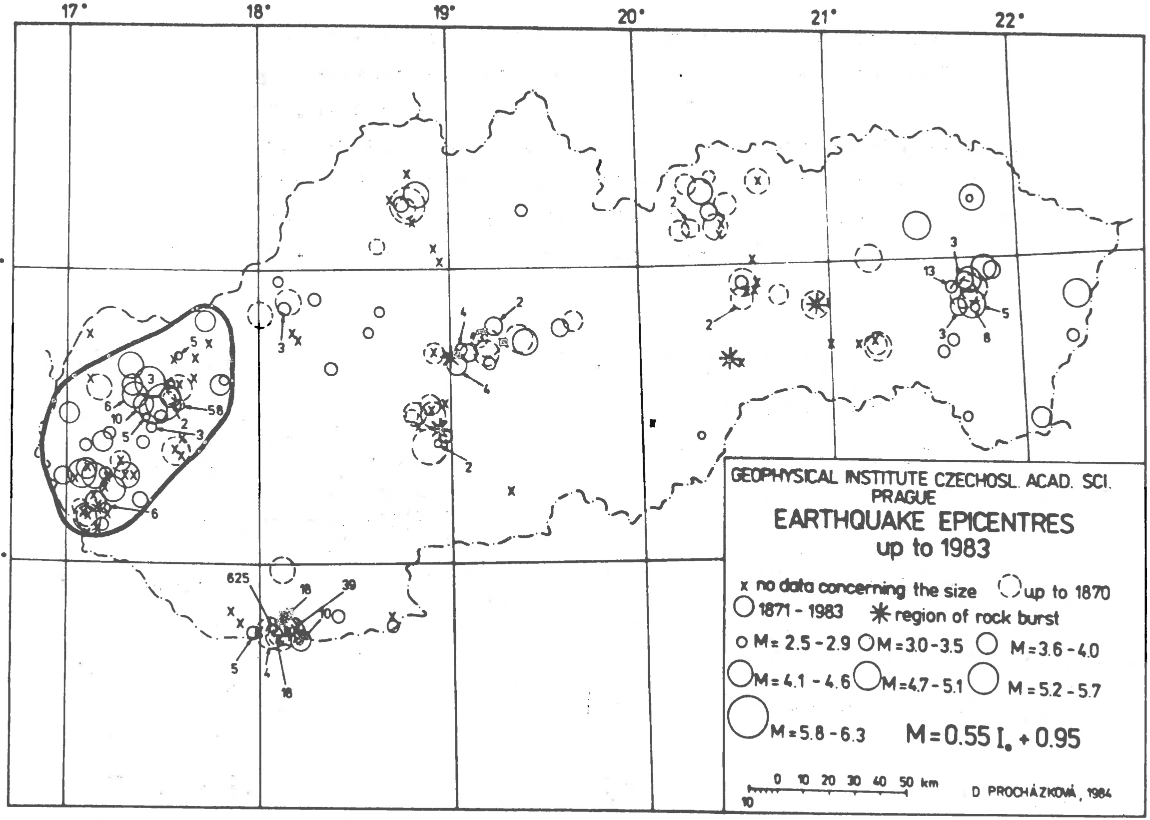

Fig. 2. Earthquake epicentres in Slovakia, $I_o \geq 2.5^o$ MSK-64; full line denotes the Little Carpathians.

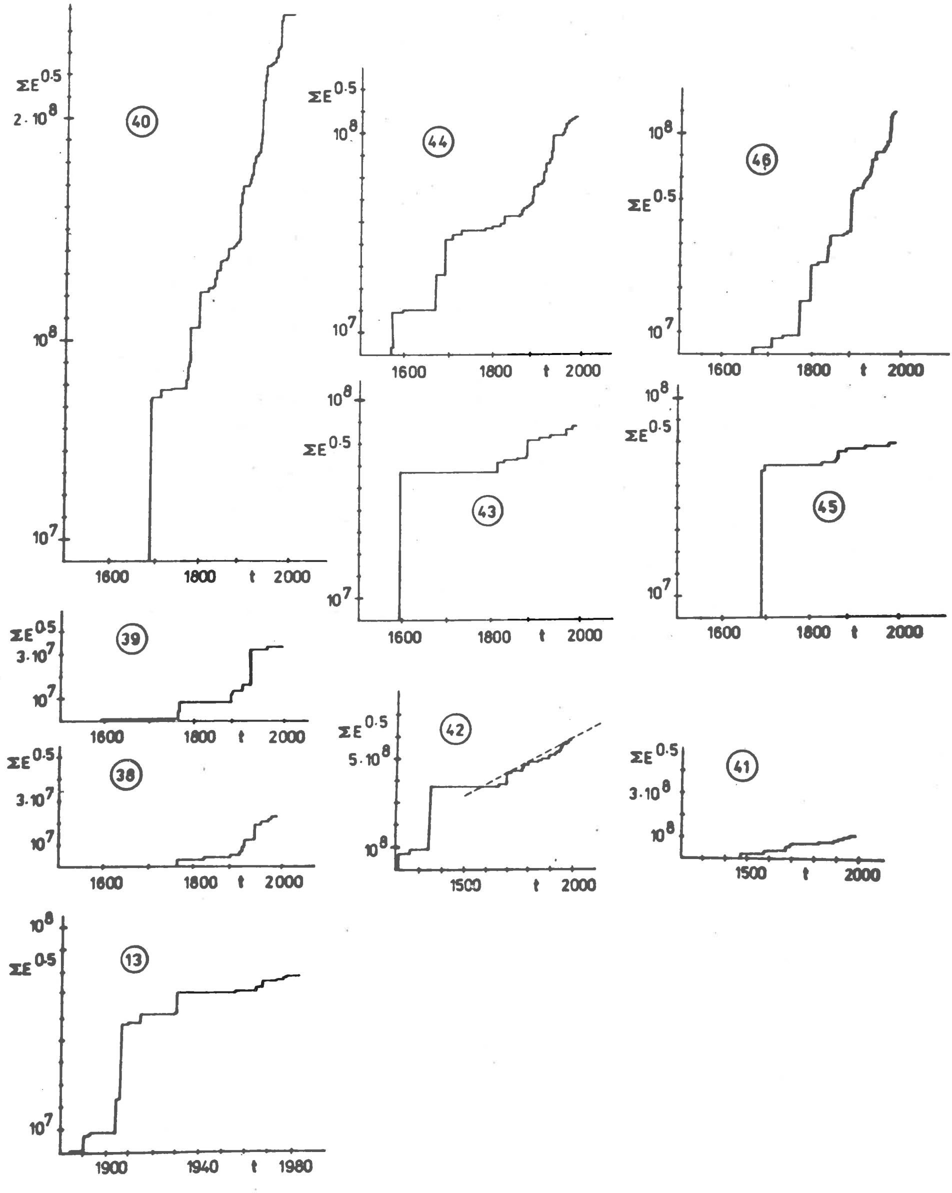

Fig. 4. Benioff´s graphs in:
13 - Little Carpathians; 38 - Strassburg, Judenburg; 39 - Vicinity of Schwadorf; 40 - Mur, Mürz, Leitha; 41 - Vicinity of Innsbruck, 1400 - 1983; 42 - Mur, Mürz, Leitha 1200 - 1983; 43 - Admont, Scheibbs, Neulengbach; 44 - Vicinity of Innsbruck; 45 - Villach, Strassburg; 46 - Leoben, Wiener Neustadt.

EVOLUTIONARY SOURCE SPECTRA $\dot{M}_t(w)$ AND RUPTURE PROCESS PATTERN OF EARTHQUAKES FROM EVOLUTIONARY BODY-WAVE MAGNITUDES $m_t(T)$ - A NEW APPROACH

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The actual spectral representation of the rupture process of earthquakes is based on underlying probabilistic characteristics of stationary stochastic processes (Aki,1967). The source spectrum $\dot{M}(w)$, or moment rate spectrum, gives the distribution of source strength over all frequencies, over the entire source process duration, and allows to define the body-wave magnitude by log $\dot{M}(w) \sim m(T=2\pi/w)$. However, the rupture process is evolving in time, rendering idfferent paterns of a large variability in the moment release over the fault plane. Therefore, another kind of source spectruem, $\dot{M}_t(w)$, underlyed by nonstationary stochastic processes whose probabilistic structure changes with time, is introduced as the "evolutionary source spectrum around time t", i.e. time-dependent. This gives the background for defining the corresponding evolutionary magnitude at time t, by $m_t(T=2\pi/w)$. Thus $m_t(T)$ are generalized magnitudes relative to the (time- domain) magnitudes: of Gutenberg $m(\bar{T}\sim 7s)$ or $m_{max}(\bar{T}=1.5s)$. The family $\{m_t(T)\}$, for all t and T, represents the evolutionary magnitude "spectrum" at a certain station (Purcaru, 1984, 1985), and may reveal rupture process patterns of complex-multiple earthquakes from the P-wave group.

DETERMINATION OF QUALITY FACTOR Q BY STRONG GROUND MOTION ANALYSIS IN THE AMPLITUDE DOMAIN

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1. Introduction

The attenuation properties of a medium are known to affect substantially the dynamics of seismic wave propagation. It is not always possible, however, to determine these properties with sufficient reliability. The most frequently applied method is to compare the amplitudes of the same wave phase and to derive the attenuation coefficients of the medium from their relationship. The method of determining the attenuation characters of seismic motions described below is based on determination of the attenuation coefficient of particle ground motions. It makes use of the amplitude analysis of a seismic wave (Schenk 1985a, 1986), which allows the coefficient to be determined directly. It can subsequently be used to deriving the attenuation coefficient of the amplitudes of seismic wave motion with distance as well as the now currently used quality factor Q.

In this work we shall first describe the theoretical background of the amplitude analysis of a seismic wave related to the attenuation coefficient, and then its practical application to the set of records of particle acceleration (accelerograms) obtained in the San Fernando epicentral region in 1971. The determination of the attenuation characteristics of seismic wave motion and of the quality factor Q relevant to these records will be presented.

2. Attenuation and Amplitude Analysis of Seismic Waves

A record of seismic particle motion in a geological medium is the resultant of the action of various wave types and their phases arriving at the observation place at different times and from different directions. In the first approximation it can thus be presumed that the record consists of a series of individual seismic signals, whose character can be expressed by a simple motion described by the differential equation in the form

$$\frac{d^2x}{dt^2} + \frac{\delta}{m}\frac{dx}{dt} + \frac{\varkappa}{m} x = 0 \quad , \tag{1}$$

where δ is the constant of proportionality between the medium resistance (proportional to the inner friction of the medium) and the velocity of a particle motion, $\varkappa$ is the constant of proportionality giving the value of the force that caused the harmonic motion in direction x, m being the weight of the particle. The solution of equation (1) yields the amplitude A in direction x at arbitrary time t

$$A = A_0 \, e^{-\beta t} \cos \omega t \quad , \tag{2}$$

where $\beta = \delta / 2m$ is the constant (or coefficient) of attenuation of a particle motion with time and $\omega = \sqrt{\omega_o^2 - \beta^2}$ is the angular frequency ; ω_o is the angular frequency in time t_0 when the amplitude of a particle from its equilibrium position in direction x was the greatest ($A = A_0$). From relation (2) it ensues that the amplitudes of the motion A having originated decay with time according to the relation

$$A = A_0 \exp (-\beta t) \tag{3}$$

and the angular frequency ω is in indirect proportion to the attenuation coefficient since it holds

$$T = 2\pi (\omega_o^2 - \beta^2)^{-1/2} \quad . \tag{4}$$

Hence it follows that the relationship of two amplitudes in time t and $(t+T)$ is constant, i.e.

$$A_t / A_{t+T} = \exp (\beta T) \quad . \tag{5}$$

It is referred to as the particle attenuation .

As relation (3), corresponding to the envelope of absolute values of particle motion amplitudes with time, is a continuous and purely monotonous function over the entire interval of the values of time t, there is also an "quasi" inverse function to this function in the following form

$$t = t_0 \exp (-\beta A) \quad , \tag{6}$$

This equation makes it possible to transfer the strong ground motion analysis from the time domain to the amplitude domain.

In analyzing the time patterns of particle motions in the amplitude domain, we determine the number of occurrences N of the sampled amplitudes in individual amplitude classes of a constant magnitude ΔA (Schenk 1985a, 1985b). Relation (3) makes it evident that the decay of the amplitudes of the attenuated motion by a constant difference of amplitudes ΔA (amplitude class) coresponds to the exponential law, which means that the decay of the lower motion amplitudes by the ΔA value lasts a longer time period than the same decay in the range of higher amplitudes. We can write

$$t_j - t_i = N \Delta t \quad , \tag{7}$$

where times t_j and t_i are those between which amplitude A_i attenuates to amplitude A_j , Δt being the time step of the record sampling. From relation (3) it then follows that

$$\left| A_j - A_i \right| = A_0 \exp\left[-\beta (t_j - t_i) \right] \quad , \tag{8}$$

and the "quasi" inverse function to relation (8) can be written in the following form

$$(t_j - t_i) = t_0 \exp\left[- \beta \left| A_j - A_i \right| \right] \quad . \tag{9}$$

After taking the logarithm, we obtain the following relation

$$\ln (t_j - t_i) = \ln t_0 - \beta \left| A_j - A_i \right| \quad , \tag{10}$$

which after the introduction of relation (7) can be re-written into the form of the amplitude-frequency distribution of ground motion amplitudes (Schenk 1985a)

$$\ln N = \ln N_S - \beta K \quad , \tag{11}$$

where $N_S = (\tau_S + \Delta t) / \Delta t$ is the total number of the amplitude samples of the investigated seismic signal of an overal duration τ_S , and K is the order of the amplitude class $\Delta A = A_j - A_i$ in the amplitude-frequency distribution.

We distinguish density and cumulative amplitude-frequency distributions (Schenk 1985a, 1985b, 1986), which can be expressed either in dependence on the amplitude class order (K is the ordinal number of the class counted from the lowest amplitude level) or in dependence on the absolute amplitude A of the particle ground motion. The way of determining the distributions and the manner of their interpretation were published earlier (Schenk 1985a, etc.). In these works, common logarithms were used to determining amplitude-frequency distributions, therefore it can be shown that relation (12) is equivalent to relation (11)

$$\log \Sigma N = \alpha_C - \beta_{C(K)} K , \tag{12}$$

in which

$$\alpha_C = \ln N_S \log e \tag{12a}$$

and

$$\beta_{C(K)} = \beta \log e . \tag{12b}$$

For the attenuation coefficient β of the particle ground motion it thus holds

$$\beta = \beta_{C(K)} / \log e . \tag{13}$$

From constant β, which characterizes the attenuation of particle motion with time, we can also determine attenuation constant γ of the motion with distance found in the following relation

$$A = A_0 e^{-\gamma R} \sin \omega \left(t - \frac{R}{c} \right) , \tag{14}$$

where R is the distance from the source and c is the velocity of a seismic wave propagation through the medium. Provided we know velocity c, then it holds

$$\gamma = \beta / c . \tag{15}$$

In seismological practice, however, we frequently use the quality factor Q to express the attenuation of seismic motion. The factor Q determines the relation of the total energy E carried by a seismic wave to the mean value of the energy ΔE attenuated during one vibration period, multiplied by 2π, i.e.

$$Q = 2\pi (E / \Delta E) . \tag{16}$$

Consequently, Q is a dimensionless quantity dependent on vibration frequency f.

For weakly attenuated motions, which also involve seismic waves that propagate through a solid geological medium, we can write

$$Q \cong \pi f / \beta . \tag{17}$$

Large values of the quality factor Q correspond to a weak attenuation of the particle motions. In solid rocks it varies within a value range of 25 to 1400 (Kittel et al. 1965, Clark 1966).

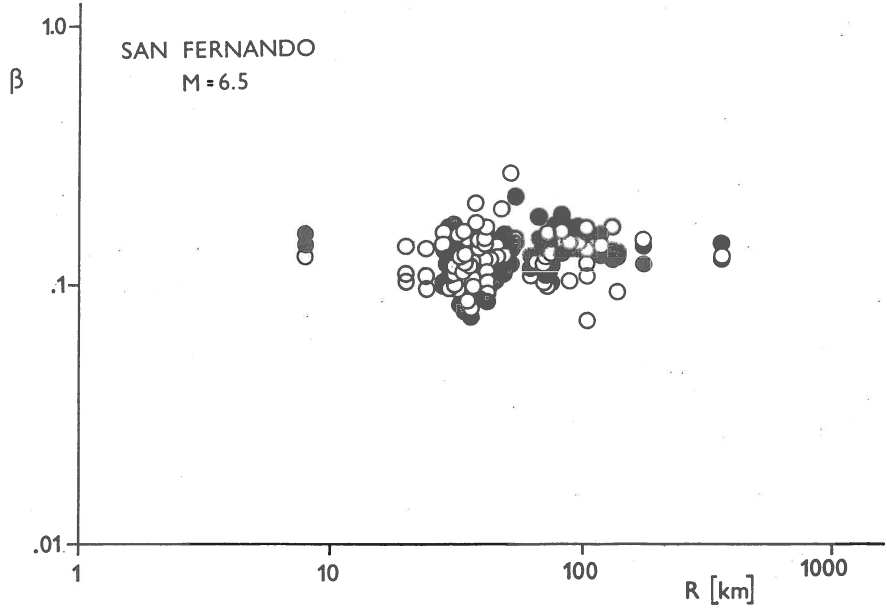

Figure 1.

3. Results and Discussion

In Schenk (1985a, 1985b), changes of coefficient $\beta_{C(K)}$ of the amplitude-frequency distribution (12) were investigated with respect to earthquake magnitude and epicentral distance R . Coefficient $\beta_{C(K)}$ proved to be invariant with respect to these two source parameters, its behaviour thus confirming the validity of relation (13), to the effect that $\beta_{C(K)}$ expresses the attenuation of the medium and is independent on the properties of the seismic source. Figure 1 demonstrates the dependence of coefficient β , obtained from (13), on the distance given by an analysis of the accelerograms measured in the near-field zone of the 1971 San Fernando earthquake, California. Full dots denote the horizontal components of ground motion, vacant dots the vertical ones. We can see that the coefficient β varies within a value range of $0.115 \div 0.138\ sec^{-1}$ (the mean value of $\tilde{\beta} = 0.129\ sec^{-1}$) and that there is no distinct difference in these values in dependence on the motion component.

Another parameter that characterizes the attenuation of seismic ground motion with distance is the attenuation constant

γ. To be able to determine it, we have to know the propagation velocity of seismic waves in the mdium. For the epicentral region of the 1971 San Fernando earthquake, Tucker and Brune (1973) applied a velocity of 3.5 km/sec to S waves and to P waves a velocity of 6.0 km/sec . From relation (15) it thus follows that γ_P is within a value range of 0.0192 to 0.0230 km^{-1} (the mean value of $\tilde{\gamma}_P$ equals 0.0215 km^{-1}), and γ_S is within a value range of 0.0329 km^{-1} to 0.0394 km^{-1} (the mean value $\tilde{\gamma}_S$ equals 0.0369 km^{-1}). Since coefficient β was determined from the complete accelerograms measured in the epicentral region of the San Fernando earthquake, in which the wave groups of P and S waves are not yet distingly developed and therefore cannot be reliably separated from each other and analyzed independently, the established coefficients γ_P and γ_S have to be regarded as informative ones.

In order to be able to determine the value of the quality factor Q , we have to know the predominant frequency of seismic motions. As in most cases the Fourier spectra of the analyzed accelerograms exhibit more maxima corresponding to several different frequencies, we decided to adopt a simplified approach to the assessment of the predominant frequency. The procedure makes use of the frequency distribution of the motion half-period recorded. For each record we defined the time intervals given by the passages of the vibrating particle through zero position. These intervals were considered to be the half-periods of the motion. We approximated the frequency distribution of the logarithms of these half-periods by the polynomial of the second order presuming its maximum value to correspond to the predominant period. The occurrence of the half-periods that corresponded to seismic noise was eliminated from the distribution. The predominant frequency of seismic motion determined in this way is $f = 8.008 \pm 4.073$ Hz . If we substitute this value into relation (17), we find that the quality factor Q may vary in dependence on values β and f within a range of 90 to 330, its mean value being $\tilde{Q} = 195^{+24}_{-13}$. Tucker and Brune (1973) assessed the quality factor Q for the San Fernando region at the value of 250 . It can be found in the interval of Q values defined by us and differs from the mean value by 20 % .

To verify the general validity of relation (17), we studied the dependence of coefficient β on the predominant frequency f

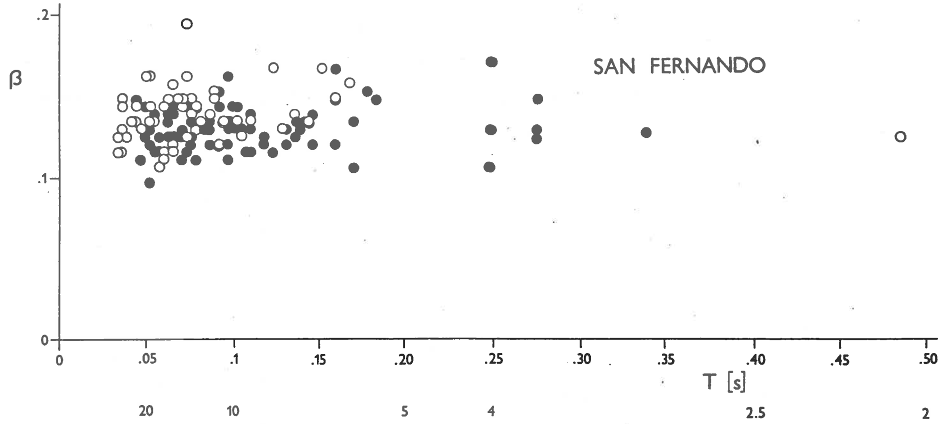

Figure 2.

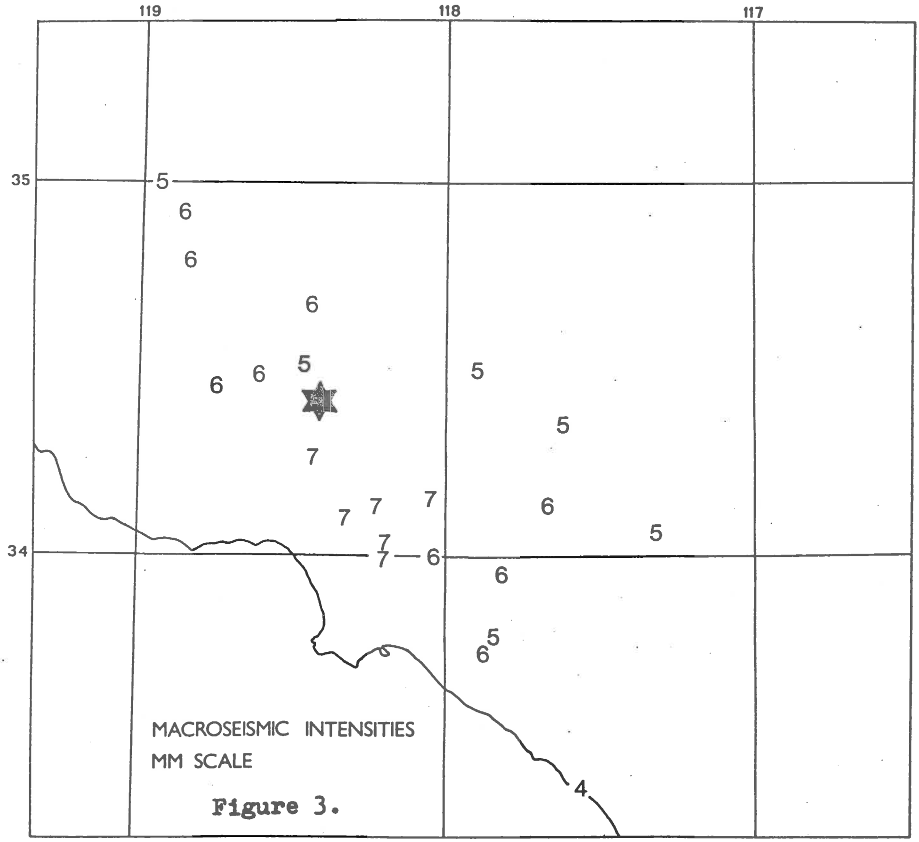

Figure 3.

(Fig. 2) . Even though the scatter of individual observations is not negligible, it can be supposed that β is not dependent on f. If we adopt this point of view in considering the validity of relation (17), we can state that the quality factor Q is a function of frequency and its magnitude does not only depend on the madium properties but also on the dynamic parameters of the motion. This viewpoint could also easily account for the 20 % difference between factor Q determined by us and factor Q given by Tucker and Brune (1973).

The relationship of coefficient β to the macroseismic intensity is documented in Figures 3 and 4, compiled from the data on the San Fernando earthquake in 1971. Figure 3 gives the values

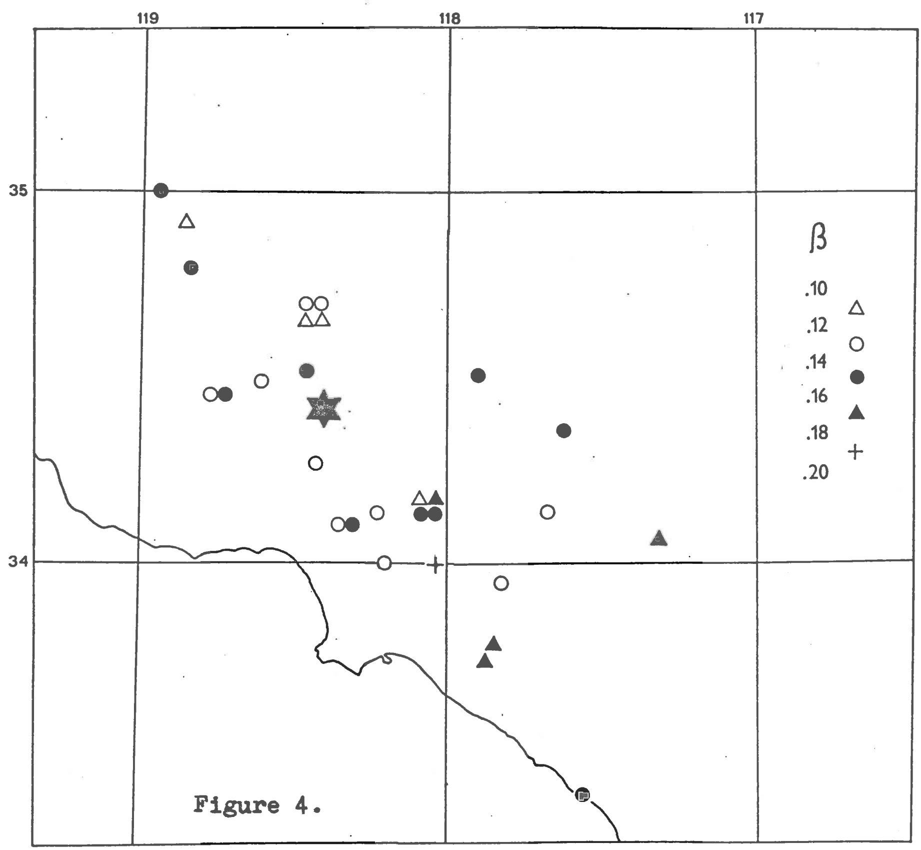

Figure 4.

of macroseismic Modified Mercalli Intensity in the places, where even direct measurements of the acceleration records were made; the asterisk in Fig. 3 denotes the epicentre. We can see that stronger macroseismic effects were generally observed in the direction to the south and southeast than to the north or northeast. Provided these effects are in indirect proportion to the value of the coefficient of seismic motion attenuation, it should hold that the seismic energy attenuation with distance is smaller in the direction to the south or southeast than to the north or northeast. The validity of this assumption is corroborated by Fig. 4, which shows the distribution of the values of attenuation coefficient β round the epicentre of the San Fernando earthquake 1971. The values of attenuation characteristics, determined by the procedure described above, thus seem to agree with the facts established about the propagation of seismic wave motion through a medium.

If it is possible to define more accurately the dependence between coefficient β, the macroseismic intensity and the distance from the focus (taking also into account the type of the medium and the frequency content of the wave motion), we shall be able to consider the methods of transforming the observed macroseismic field into the distribution field of the attenuation or amplitude characteristics expressed in effective values (Schenk 1985a).

4. Conclusion

The analysis of the records of seismic wave motion in the amplitude domain enables the attenuation coefficient β of particle motions to be determined directly. With the knowledge of the predominant frequency f of the seismic wave motion and of the velocity c of its propagation through the medium, this coefficient can be applied to the determination of quality factor Q and of the change of attenuation coefficient γ of wave motion with distance (see relations (15) and (17)). The applicability of the present procedure was verified on the accelerograms measured in the San Fernando 1971 epicentral earthquake zone.

In studying the dependence of coefficient β, actually $\beta_{C(K)}$, on the predominant frequency, we found (Fig. 2) its value to be virtually independent on the frequency. Since it is a result obtained from an analysis of the wave motion of one earthquake, San Fernando 1971, it is essential to use more material in order to verify the mentioned fact because its general validity would influence also some conclusions in determining the attenuation characteristics of a medium. Moreover, for the records measured in far-field distances it will be necessary to define the effect of a seismic wave type (P, S, surface) on the attenuation coefficients, on coefficient γ in particular. We believe that after these relations have been defined more closely, the present method of determining the quality factor Q and attenuation coefficients β and γ will make seismic interpretations more dependable.

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CLASSIFICATION OF STRONG GROUND MOTIONS ACCORDING TO MACROSEISMIC INTENSITY BY PATTERN RECOGNITION ALGORITHMS

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1. Introduction

Strong motion studies have commanded much attention in the recent decades. Two main trends can be observed : (i) investigations into earthquake processes in the near zone of the focus, and (ii) investigations in the field of engineering seismology and structural or design engineering. Our paper belongs to the latter and the following questions are studied :

a) which parameters of the strong motion records give distinct information on its destructive force and
b) which combination of these parameters characterize the record according to its macroseismic effect.

From the catalogue (volume A-N) of the Californian Institute of Technology some accelerograms of the earthquakes (1940-1971) recorded on the open surface and in the foundations of buildings were analyzed in the amplitude domain. The records were divided into three classes according to Modified Mercalli MM Intensities observed where accelerographs were installed :

1) with intensity equal to and greater than 7° MM (destructive effects),
2) with intensity of 6°=MM (moderate effects), and
3) with intensity equal to or smaller than 5° MM (safe effects).

This classification was necessitated by the statistical significance of the number of records of acceleration (objects) in each macroseismic class. For our analysis the MM Intensities were taken from McGuire and Barnhard (1977) and Earthquakes in the USA (Boulder). Our paper contains a brief review of the dynamical parameters, which can be obtained in the amplitude domain, and the relationship of these parameters to the macroseismic effects. For this study the pattern recognition algorithms given in the Appendix were used. A classification of strong motion records with respect to the macroseismic effects is one of the most frequent problems in the present practice. It constitutes the basis for selecting analogous accelerograms, which are needed for the design of earthquake resistant structures.

2. Description of Strong Motion Parameters

The analysis of seismic waves in the amplitude domain extends the current methods of studying the dynamical parameters of seismic waves applied in the time and frequency domains. Analyzing a ground motion in the amplitude domain, we have to calculate first the amplitude-frequency distribution AFD (Schenk 1985a). In principle, we distinguish density and cumulative AFDs, and we can express them either in dependence on the absolute value of the amplitude A of the ground motion or in dependence on the order of the amplitude class K in the set. For density AFD we thus write

$$\log N = a_D - b_{D(A)} A \quad , \qquad (1a)$$

$$\log N = a_D - b_{D(K)} K \quad , \qquad (1b)$$

and for cumulative AFD

$$\log N = a_C - b_{C(A)} A \quad , \qquad (2a)$$

$$\log N = a_C - b_{C(K)} K \quad , \qquad (2b)$$

where N is the number of seismic wave amplitudes (amplitude samples) that belong to the amplitude class K, coefficients a_D, a_C, $b_{D(A)}$, $b_{D(K)}$, $b_{C(A)}$ and $b_{C(K)}$ are determined by the least square method (Schenk 1985b).

The knowledge of density and cumulative AFDs enables us to establish new, as yet unused parameters of seismic wave motion. In essence, it involves three types of data : (i) data of amplitude character, (ii) data on the energy content of wave motion and (iii) data characterizing the time duration of the signal. Since a detailed analysis of the relationships of most of the above-mentioned quantities to earthquake parameters (magnitude, epicentral distance, macroseismic intensity) was performed earlier (Schenk 1985a), in the next part of the present work we shall only confine ourselves to defining these quantities.

The statistically determined maximum amplitude of the seismic signal is given by the relation

$$A_{max(s)} = a_D / b_{D(A)} . \quad (3)$$

Value $A_{max(s)}$ is determined by the level of the occurrence of one amplitude sample in the standard density AFD. $A_{max(s)}$ thus determined is dependent on the whole pattern of the AFD and can be considered as a more representative value of the maximum amplitude of the seismic signal than a possible random extreme amplitude of A_{max} in the record.

Likewise, the "reference" maximum amplitude of the seismic signal can be determined from the cumulative AFD by the relation

$$A_{max(ref)} = a_C / b_{C(A)} . \quad (4)$$

The effective amplitudes of the seismic signal are defined by their percentile occurrence P [%] in the whole wave pattern and are given by the following relation

$$A_{eff}(P) = \left[a_C + \log (P/100) \right] / b_{C(A)} \quad (5)$$

where $P \geqslant 100 / 10^{a_C}$.

The total value of the root-mean-square (RMS) amplitude of the seismic signal is defined as follows

$$RMS = \left\{ \left[\sum_{i=1}^{m} A_i N_i \right] / \left[\left(\sum_{i=1}^{m} N_i \right) - 1 \right] \right\}^{1/2} . \quad (6a)$$

where

$$N_i = \left| 10^{a_D - b_{D(A)} A_i} \right| , \quad (6b)$$

$$A_i = (2i - 1) A_{max} / 2 K_{max} , \quad (6c)$$

index m is the upper limit of the summation, which is determined by these conditions : for $\log N_i \geqslant 0$ it holds $1 \leqslant i \leqslant m$, and for $\log N_i < 0$ it holds $m \leqslant i \leqslant K_{max}$.

The total amount of the kinetic energy contained in the seismic signal can be determined from the relation

$$E = \left[(\Delta t / \tau_s) + 1 \right] \sum_{i=1}^{m} A_i^2 N_i , \quad (7)$$

where N_i and A_i are given by relations (6b) and (6c), τ_s being the total time duration of the signal (see below).

In order to obtain the energy values in standard physical units erg or Joule , it is essential that the digitized amplitudes should correspond to the particle velocity.

The total impulse of the seismic signal, whose amplitudes are expressed in the particle acceleration, is given by the following relation

$$IMP = \left[(\Delta t / \tau_s) + 1 \right] \sum_{i=1}^{m} A_i N_i \quad . \qquad (8)$$

The total time duration of the seismic signal τ_s is given by the number of all amplitude samples of the signal N_C and by the sampling interval Δt . We can write

$$\tau_s = (N_C - 1) \Delta t \quad , \qquad (9a)$$

where

$$\log N_C = a_C - b_{C(A)} (\Delta A / 2) \qquad (9b)$$

and

$$\Delta A = A_{i+1} - A_i \quad . \qquad (9c)$$

The effective time durations of the seismic signal are related to the effective amplitudes $A_{eff}(P)$ set beforehand, and they are given by the relation

$$\tau_{eff} A_{eff}(P) = (N_{eff} - 1) \Delta t \quad , \qquad (10a)$$

where

$$\log N_{eff} = a_C - b_{C(A)} A_{eff}(P) \quad . \qquad (10b)$$

3. Significance of the Parameters for Record Classification according to Macroseismic Intensity

First the parameters described in the previous paragraph were determined for the accelerograms of the Californian earthquakes and then statistically analyzed. The statistical analysis was performed for vertical and horizontal components separately and for three macroseismic classes (Table 1). Each component was considered to be one object characterized by a vector of the parameters.

Table 1	macroseismic class		
	class 1	class 2	class 3
	$I \geqslant 7^\circ$	$I = 6^\circ$	$I \leqslant 5^\circ$
vertical component	47	29	11
horizontal component	95	58	26

The multidimensional dispersional analysis can be used under the assumption that inside each class the vectors of the parameters are normally distributed with respect to the mean vector of this class and that the covariation matrixes of the vectors of the three macroseismic classes are equal (Appendix, points 1 and 2). We have to note that the parameters characterizing amplitude (RMS, $A_{eff}(80)$, $A_{eff}(90)$, $A_{eff}(95)$, $A_{eff}(98)$, $A_{eff}(99.5)$, A_{max}, $A_{max(s)}$ and $A_{max(ref)}$) and energy (E, IMP) quantities were taken in the logarithmic form to make their distributions inside the classes closer to the normal ones.

The mean values of the parameters (e.g. the components of the mean vector), together with their standard deviations, were determined separately for vertical (Table 2.) and for horizontal (Table 2.) components of acceleration. Applying the F-statistics (Ahrens and Läuter 1981) to these mean values one can find that the mean vectors of all the three macroseismic classes differ with a confidence level of 0.01 . Table 3a contains the coefficients of correlation of the parameters of vertical components, Table 3b of horizontal components.

Now we are going to estimate the way each parameter can contribute to the classification of vertical and horizontal components into the three macroseismic classes mentioned above. The statistical quantity "distance" D of each parameter was introduced to this evaluation (Appendix, point 3, and Ahrens and Läuter, 1981). The higher the D (Table 2.), the more informative the parameter for the classification. For example, we see that the A_{max} of vertical and horizontal components are less informative than $A_{eff}(80)$ and $\tau_{eff}(100)$.

After the statistical analysis of the parameters, the pattern recognition algorithms were introduced to solve the inverse problem : a classification of the accelerogram, which is described by the 25 parameters of each of its components according to macroseismic effects. We used the following algorithms (Appendix, point 4) :

i) MAH - based on the Mahalanobis distance,

ii) FACT - the estimate of F-statistics (unbiased estimate of MAH),

iii) APR - the estimate with regard to "a priori" probabilities of classes,

iv) DCOR - the estimate with regard to different covariations in classes, and

Table 2.

vertical component							
Parameter	class 1		class 2		class 3		D
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
RMS	.82	.14	.73	.15	.72	.15	.11
E	3.63	.57	3.27	.58	2.92	.48	.21
IMP	.03	.27	-.16	.30	-.21	.31	.13
Ae80	2.32	.27	2.04	.33	1.79	.20	.48
Ae90	2.44	.30	2.24	.29	1.95	.19	.37
Ae95	2.56	.28	2.36	.30	2.06	.19	.38
Ae98	2.65	.28	2.46	.31	2.15	.19	.36
Ae99	2.70	.29	2.51	.31	2.20	.19	.35
taus	34.35	21.39	28.67	26.10	36.74	28.30	.02
te05	31.59	18.33	24.60	19.45	29.93	21.94	.03
te10	29.21	15.97	21.36	14.91	24.52	17.13	.06
te20	25.27	12.67	16.61	9.94	16.74	10.71	.15
te40	19.52	9.44	11.08	6.93	8.33	4.94	.34
te65	14.68	7.80	7.50	5.61	3.86	2.66	.42
te100	10.31	6.46	4.85	4.30	1.52	1.46	.40
logF	1.11	.22	1.12	.22	1.10	.22	.00
Amax	2.82	.29	2.66	.33	2.30	.21	.35
aD	2.14	.29	2.03	.37	2.08	.33	.03
bD	-.01	.01	-.01	.01	-.01	.01	.16
aC	3.16	.27	3.01	.36	3.19	.24	.06
bC	-.01	.01	-.01	.01	-.02	.01	.20
bDK	-.05	.01	-.05	.01	-.05	.01	.04
bCK	-.06	.01	-.06	.01	-.06	.01	.03
As	2.74	.29	2.56	.32	2.25	.20	.34
Aref	2.84	.30	2.67	.32	2.34	.19	.33

horizontal component							
Parameter	class 1		class 2		class 3		D
	Mean	S.D.	Mean	S.D.	Mean	S.D.	
RMS	.95	.15	.85	.15	.82	.16	.14
E	4.22	.53	3.77	.62	3.39	.57	.31
IMP	.28	.28	.09	.30	.01	.33	.14
Ae80	2.58	.30	2.32	.34	2.02	.27	.44
Ae90	2.75	.27	2.48	.38	2.19	.26	.44
Ae95	2.87	.27	2.64	.31	2.31	.26	.50
Ae98	2.97	.27	2.75	.32	2.40	.26	.49
Ae99	3.02	.27	2.81	.32	2.45	.27	.47
taus	28.74	19.07	24.24	24.52	29.72	25.97	.01
te05	27.70	17.94	22.58	21.87	26.10	21.74	.01
te10	26.74	16.93	21.08	19.58	23.03	18.37	.02
te20	25.00	15.20	18.48	15.89	18.18	13.45	.05
te40	22.04	12.61	14.52	11.11	11.88	7.96	.14
te65	19.05	10.50	11.13	7.96	7.49	5.10	.27
te100	15.76	8.82	8.12	5.93	4.35	3.71	.39
logF	-.26	11.73	.39	6.41	2.11	6.88	.01
Amax	3.14	.28	2.96	.35	2.59	.28	.38
aD	2.03	.28	1.95	.40	2.06	.33	.02
bD	.00	.00	.00	.00	-.01	.01	.34
aC	3.08	.27	2.91	.38	3.07	.28	.06
bC	.00	.00	.00	.00	-.01	.01	.35
bDK	-.05	.01	-.05	.01	-.05	.01	.03
bCK	-.06	.01	-.06	.01	-.06	.01	.04
As	3.06	.28	2.85	.33	2.49	.27	.47
Aref	3.17	.28	2.98	.33	2.60	.27	.46

Table 3a.

Correlation Matrix of the Parameters of Vertical Components

	RMS	E	IMP	Ae80	Ae90	Ae95	Ae98	Ae99	taus	te05	te10	te20	te40	te65	te100	logF	Amax	aD	bD	aC	bC	bDK	bCK	As	Aref
RMS	1.00	.91	.99	.79	.77	.73	.70	.68	-.06	.02	.10	.27	.50	.61	.64	.29	.63	.03	.55	.07	.55	.07	.10	.67	.66
E	.91	1.00	.94	.87	.95	.92	.90	.89	-.27	-.18	-.09	.11	.42	.61	.70	.37	.85	-.16	.73	-.14	.73	.16	.17	.88	.87
IMP	.99	.94	1.00	.80	.81	.78	.76	.74	-.14	-.06	.03	.20	.46	.59	.64	.34	.71	-.05	.61	-.03	.61	.08	.09	.73	.72
Ae80	.79	.87	.80	1.00	.91	.89	.86	.85	-.09	-.01	.08	.26	.52	.66	.73	.33	.79	.02	.65	.05	.67	.08	.12	.83	.82
Ae90	.77	.95	.81	.91	1.00	.97	.94	.93	-.23	-.15	-.05	.14	.44	.63	.73	.34	.89	-.13	.74	-.11	.75	.15	.17	.92	.90
Ae95	.73	.92	.78	.89	.97	1.00	1.00	.99	-.35	-.27	-.18	.02	.35	.57	.69	.43	.97	-.32	.82	-.29	.82	.30	.29	.99	.98
Ae98	.70	.90	.76	.86	.94	1.00	1.00	1.00	-.40	-.32	-.24	-.04	.30	.52	.66	.46	.98	-.39	.84	-.36	.84	.36	.34	1.00	.99
Ae99	.68	.89	.74	.85	.93	.99	1.00	1.00	-.42	-.35	-.26	-.07	.27	.50	.64	.47	.99	-.43	.84	-.39	.84	.39	.36	1.00	1.00
taus	-.06	-.27	-.14	-.09	-.23	-.35	-.40	-.42	1.00	.99	.96	.83	.50	.22	.04	-.41	-.50	.87	-.51	.90	-.49	-.55	-.56	-.44	-.47
te05	.02	-.18	-.06	-.01	-.15	-.27	-.32	-.35	.99	1.00	.99	.90	.61	.33	.14	-.39	-.43	.87	-.41	.92	-.39	-.54	-.55	-.37	-.40
te10	.10	-.09	.03	.08	-.05	-.18	-.24	-.26	.96	.99	1.00	.96	.72	.45	.26	-.35	-.35	.86	-.30	.91	-.28	-.51	-.52	-.28	-.31
te20	.27	.11	.20	.26	.14	.02	-.04	-.07	.83	.90	.96	1.00	.89	.67	.48	-.25	-.16	.79	-.09	.85	-.07	-.43	-.43	-.09	-.12
te40	.50	.42	.46	.52	.44	.35	.30	.27	.50	.61	.72	.89	1.00	.93	.80	-.04	.18	.53	.24	.62	.26	-.22	-.22	.25	.23
te65	.61	.61	.59	.66	.63	.57	.52	.50	.22	.33	.45	.67	.93	1.00	.96	.12	.43	.28	.42	.37	.42	-.04	-.05	.49	.47
te100	.64	.70	.64	.73	.73	.69	.66	.64	.04	.14	.26	.48	.80	.96	1.00	.22	.58	.10	.47	.19	.48	.08	.06	.63	.61
logF	.29	.37	.34	.33	.34	.43	.46	.47	-.41	-.39	-.35	-.25	-.04	.12	.22	1.00	.49	-.46	.43	-.40	.42	.38	.29	.48	.48
Amax	.63	.85	.71	.79	.89	.97	.98	.99	-.50	-.43	-.35	-.16	.18	.43	.58	.49	1.00	-.49	.85	-.49	.85	.35	.32	.99	.99
aD	.03	-.16	-.05	.02	-.13	-.32	-.39	-.43	.87	.87	.86	.79	.53	.28	.10	-.46	-.49	1.00	-.50	.94	-.46	-.78	-.68	-.45	-.48
bD	.55	.73	.61	.65	.74	.82	.84	.84	-.51	-.41	-.30	-.09	.24	.42	.47	.43	.85	-.50	1.00	-.47	1.00	.40	.37	.85	.85
aC	.07	-.14	-.03	.05	-.11	-.29	-.36	-.39	.90	.92	.91	.85	.62	.37	.19	-.40	-.49	.94	-.47	1.00	-.45	-.55	-.51	-.41	-.44
bC	.55	.73	.61	.67	.75	.82	.84	.84	-.49	-.39	-.28	-.07	.26	.42	.48	.42	.85	-.46	1.00	-.45	1.00	.36	.35	.85	.85
bDK	.07	.16	.08	.08	.15	.30	.36	.39	-.55	-.54	-.51	-.43	-.22	-.04	.08	.38	.35	-.78	.40	-.55	.36	1.00	.91	.41	.43
bCK	.10	.17	.09	.12	.17	.29	.34	.36	-.56	-.55	-.52	-.43	-.22	-.05	.06	.29	.32	-.68	.37	-.51	.35	.91	1.00	.38	.42
As	.67	.88	.73	.83	.92	.99	1.00	1.00	-.44	-.37	-.28	-.09	.25	.49	.63	.48	.99	-.45	.85	-.41	.85	.41	.38	1.00	1.00
Aref	.66	.87	.72	.82	.90	.98	.99	1.00	-.47	-.40	-.31	-.12	.23	.47	.61	.48	.99	-.48	.85	-.44	.85	.43	.42	1.00	1.00

Table 3b.

Correlation Matrix of the Parameters of Horizontal Components

	RMS	E	IMP	Ae80	Ae90	Ae95	Ae98	Ae99	taus	te05	te10	te20	te40	te65	te100	logF	Amax	aD	bD	aC	bC	bDK	bCK	As	Aref
RMS	1.00	.91	.99	.77	.78	.77	.74	.73	.06	.09	.13	.21	.34	.46	.56	-.05	.67	.13	.53	.14	.53	-.11	-.15	.71	.69
E	.91	1.00	.93	.85	.90	.92	.90	.89	-.14	-.10	-.06	.02	.18	.34	.49	-.07	.86	-.04	.69	-.04	.70	-.05	-.10	.88	.86
IMP	.99	.93	1.00	.78	.78	.80	.78	.77	-.02	.02	.05	.13	.26	.39	.50	-.04	.73	.05	.58	.05	.57	-.10	-.15	.76	.74
Ae80	.77	.85	.78	1.00	.85	.87	.84	.82	.06	.10	.14	.22	.36	.50	.61	-.13	.77	.20	.59	.18	.61	-.23	-.25	.80	.77
Ae90	.78	.90	.78	.85	1.00	.92	.88	.87	-.08	-.04	.00	.07	.22	.36	.50	-.11	.83	.06	.64	.04	.66	-.15	-.16	.85	.83
Ae95	.77	.92	.80	.87	.92	1.00	.99	.99	-.22	-.18	-.14	-.06	.10	.27	.44	-.11	.97	-.17	.78	-.18	.79	.06	.02	.98	.97
Ae98	.74	.90	.78	.84	.88	.99	1.00	1.00	-.28	-.24	-.20	-.12	.04	.21	.39	-.10	.98	-.26	.80	-.26	.81	.14	.09	1.00	.99
Ae99	.73	.89	.77	.82	.87	.99	1.00	1.00	-.30	-.27	-.23	-.15	.01	.18	.36	-.10	.99	-.30	.81	-.30	.82	.17	.12	1.00	.99
taus	.06	-.14	-.02	.06	-.08	-.22	-.28	-.30	1.00	1.00	.99	.96	.86	.71	.50	-.07	-.39	.85	-.42	.90	-.40	-.50	-.55	-.32	-.37
te05	.09	-.10	.02	.10	-.04	-.18	-.24	-.27	1.00	1.00	1.00	.98	.90	.75	.56	-.08	-.36	.86	-.37	.91	-.35	-.50	-.55	-.29	-.33
te10	.13	-.06	.05	.14	.00	-.14	-.20	-.23	.99	1.00	1.00	.99	.93	.80	.61	-.09	-.33	.86	-.31	.91	-.30	-.49	-.55	-.25	-.30
te20	.21	.02	.13	.22	.07	-.06	-.12	-.15	.96	.98	.99	1.00	.97	.87	.70	-.11	-.25	.84	-.21	.90	-.20	-.48	-.54	-.17	-.22
te40	.34	.18	.26	.36	.22	.10	.04	.01	.86	.90	.93	.97	1.00	.96	.85	-.14	-.10	.79	-.04	.86	-.03	-.43	-.51	-.01	-.07
te65	.46	.34	.39	.50	.36	.27	.21	.18	.71	.75	.80	.87	.96	1.00	.96	-.18	.07	.68	.12	.76	.13	-.35	-.44	.16	.11
te100	.56	.49	.50	.61	.50	.44	.39	.36	.50	.56	.61	.70	.85	.96	1.00	-.22	.26	.52	.26	.60	.27	-.25	-.34	.35	.30
logF	-.05	-.07	-.04	-.13	-.11	-.11	-.10	-.10	-.07	-.08	-.09	-.11	-.14	-.18	-.22	1.00	-.08	-.08	-.02	-.09	-.02	.07	.07	-.09	-.09
Amax	.67	.86	.73	.77	.83	.97	.98	.99	-.39	-.36	-.33	-.25	-.10	.07	.26	-.08	1.00	-.37	.81	-.40	.82	.15	.12	.99	.99
aD	.13	-.04	.05	.20	.06	-.17	-.26	-.30	.85	.86	.86	.84	.79	.68	.52	-.08	-.37	1.00	-.42	.95	-.39	-.79	-.74	-.33	-.37
bD	.53	.69	.58	.59	.64	.78	.80	.81	-.42	-.37	-.31	-.21	-.04	.12	.26	-.02	.81	-.42	1.00	-.40	.99	.31	.26	.81	.82
aC	.14	-.04	.05	.18	.04	-.18	-.26	-.30	.90	.91	.91	.90	.86	.76	.60	-.09	-.40	.95	-.40	1.00	-.38	-.59	-.64	-.32	-.38
bC	.53	.70	.57	.61	.66	.79	.81	.82	-.40	-.35	-.30	-.20	-.03	.13	.27	-.02	.82	-.39	.99	-.38	1.00	.26	.24	.82	.83
bDK	-.11	-.05	-.10	-.23	-.15	.06	.14	.17	-.50	-.50	-.49	-.48	-.43	-.35	-.25	.07	.15	-.79	.31	-.59	.26	1.00	.88	.19	.22
bCK	-.15	-.10	-.15	-.25	-.16	.02	.09	.12	-.55	-.55	-.55	-.54	-.51	-.44	-.34	.07	.12	-.74	.26	-.64	.24	.88	1.00	.14	.20
As	.71	.88	.76	.80	.85	.98	1.00	1.00	-.32	-.29	-.25	-.17	-.01	.16	.35	-.09	.99	-.33	.81	-.32	.82	.19	.14	1.00	1.00
Aref	.69	.86	.74	.77	.83	.97	.99	.99	-.37	-.33	-.30	-.22	-.07	.11	.30	-.09	.99	-.37	.82	-.38	.83	.22	.20	1.00	1.00

v) DAPR - the estimate with regard to all these possible distinctions between classes.

An inaccuracy of different pattern recognition algorithms applied in the process of classification is given in Table 4. We observe, for example, that the Mahalanobis algorithm MAH gives the most effective classification for the horizontal component, while the "a priori" probabilities algorithm APR gives the most effective classification for the vertical component. Table 4 also shows that the pattern recognition algorithms allow us to clasify succesfully three out of four acceleration components, the vertical or horizontal ones.

Table 4.

Pattern Recognition Algorithm	Percentage of Failures in the Classification			
	Horizontal Component		Vertical	
	I	II	I	II
FACT	24.7	3.1	24.0	2.1
MAH	24.2	3.1	25.0	2.1
DCOR	23.7	10.3	19.8	33.3
APR	25.3	3.1	22.9	2.1
DAPR	22.7	10.3	19.8	33.3

I - objects referred to the adjacent class
II - objects referred to the opposite class

4. Characteristics of "Destructive" and "Safe" Records

In this paragraph an attempt is made at establishing the characteristics of the objects belonging to the first ($I \geqslant 7^{o}MM$) and the third ($I \leqslant 5^{o}MM$) classes. These characteristics are determined by the CORA-3 algorithm of pattern recognition (Gelfand et al. 1976). This algorithm uses binary vectors (i.e. 0 and 1) to detect the characteristic features (traits) of vectors in each of the two given macroseismic classes. Each parameter is coded by 0 if higher than the corresponding threshold and by 1 if smaller than this threshold. An example of the thresholds for some more informative parameters of vertical and horizontal components is presented in Table 5. Using the CORA-3 algorithm 8 parameters were finally selected as the most informative for the classification of vertical and horizontal components of acceleration. It is also necessary to

Table 5.

Parameter	Vertical Component	Horizontal Component
a_C	3.15	2.98
$b_{C(A)}$	0.01019	0.00250
$b_{D(A)}$	0.00999	0.00210
$A_{max(s)}$	300	1146
$A_{max(ref)}$	450	1255
$A_{eff}(80)$	92	260
$A_{eff}(90)$	150	524
$A_{eff}(98)$	300	650
RMS	7.0	12.4
E	3500	15000
IMP	1.5	2.0
(s)	28.53	38.0
$\tau_{eff}(65)$	8.0	18.65
$\tau_{eff}(100)$	4.5	8.0

point out that two horizontal components of the same accelerograms create an only vector consisting of the maximum values, which were always elected from two values of the same parameter. The advantage of that approach was discussed in the past (Gvishiani et al., in press) and therefore it was applied in our study too.

The necessary criteria for a classification of accelerograms into the "destructive" class ($I \geqslant 7^{o}$MM) are the following :

A. for vertical components

1. $\tau_{eff}(65) > 8$ sec,
2. $\tau_s > 28.53$ sec, $A_{eff}(80) > 92$ cm/sec^2,
3. $A_{eff}(80) > 92$ cm/sec^2, RMS < 7 cm/sec^2,
4. $b_{C(A)} < 0.01019$, $\tau_s < 28.53$ sec, RMS < 7 cm/sec^2,

B. for horizontal components

1. $\tau_{eff}(100) > 8$ sec, $\tau_{eff}(65) > 18.65$ sec,
2. $\tau_{eff}(100) > 8$ sec, E < 15000,
3. $b_{C(A)} < 0.0025$.

Likewise, to clasify the accelerograms into the "save" class ($I \leqslant 5^{o}$MM), the following conditions have to be satisfied :

A. for vertical components

1. $\tau_{eff}(65) < 8$ sec, $A_{eff}(80) < 92$ cm/sec^2, $b_{C(A)} > 0.01019$
2. $\tau_{eff}(65) < 8$ sec, $A_{eff}(80) < 92$ cm/sec^2, $\tau_s > 28.53$sec,

3. $\tau_{eff}(65) < 8$ sec, RMS > 7 cm/sec^2,

B. for horizontal components

1. $\tau_{eff}(65) < 18.65$ sec, $\tau_{eff}(100) < 8$ sec, $b_{C(A)} > 0.0025$
2. $\tau_{eff}(65) < 18.65$ sec, $E > 15000$, $A_{max(ref)} < 1255$ cm/s^2.

The next tables show how many features of each class vertical (Table 6a) and horizontal (Table 6b) components possess. The coding of the components (e.g. M183, B023, etc.) corresponds to that used in the strong motion data bank of the Californian Institute of Technology. It follows that each component of the given class has at least one feature of its own class and no feature of the opposite class.

Table 6a.

number of votes for 3 class	number of votes for 1 class: 0	1	2	3	4
3	- M183				
2	- B023				
	- B039				
	- E071				
	- L171				
	- M180				
	- M184				
1	- A002				
	- F101				
	- F102				
	- F103				
	- F104				
0		* A001	* A004	* A006	
		* A010	* A005	* A008	
		* B025	* A007	* A018	
		* B033	* A009	* B032	
		* C041	* B028	* C054	
		* D065	* B029	* D057	
		* D068	* C048	* D058	
		* E085	* C051	* D059	
		* F088	* E075	* D062	
		* G107	* F089	* E072	
		* I135	* I137	* E078	
		* I136	* J145	* F095	
		* L173	* J148	* F098	
			* N186	* F105	
			* N188	* G106	
				* G109	
				* L166	
				* L172	
				* M176	

Table 6b.

number of votes for 3 class	number of votes for 1 class: 0	1	2	3
2	- F104			
1	- A002			
	- B023			
	- B039			
	- B040			
	- E071			
	- F101			
	- F102			
	- F103			
	- L171			
	- M180			
	- M183			
	- M184			
0		* A008	* A001	* A005
		* A009	* A004	* C051
		* A010	* A006	* D057
		* B025	* A007	* E072
		* B032	* A018	
		* B033	* B028	
		* C041	* B029	
		* D058	* C048	
		* D059	* C054	
		* D062	* E075	
		* D065	* E078	
		* D068	* E085	
		* E083	* F088	
		* F095	* F089	
		* F098	* G106	
		* F105	* G109	
		* G107	* I136	
		* J148	* I137	
		* N186	* J145	
			* L166	
			* L172	
			* L173	
			* M176	
			* N188	

5. Conclusion

The vertical and horizontal components of accelerations, recorded in California during the period 1940-1971, were analyzed in the amplitude domain (Schenk 1985a, 1985b). Some of the wave parameters were found to carry a lot of information on the macroseismic effects of ground motions : $A_{eff}(80)$, $\tau_{eff}(65)$, $\tau_{eff}(100)$ and $b_{C(A)}$.

The first step of accelerogram classification into the three macroseismic classes was carried out by various algorithms of pattern recognition. These results invariably indicated that the degree of macroseismic intensity could be evaluated directly from the record of strong motion. Nevertheless, it seems that one reason for the origin of failures in the classification is given by the very nature of the macroseismic intensity assessment. These intensities are evaluated from the observed effects, i.e. they are "categorized" into the certain degree of the macroseismic intensity and, therefore, the intensity has more or less a character of an integer with an accuracy round $\pm$ 0.5° MM.

Further, we classified the accelerograms into the two classes ($I \geqslant 7°$ MM and $I \leqslant 5°$ mm) by means of the CORA-3 algorithm. Characteristic features - combinations of parameters and their thresholds - were determined. The results show (Tables 6) that all investigated accelerograms were classified succesfully and, therefore, the features can also be used in the determination of analogous accelerograms in the present engineering-seismological practice.

Appendix

A description of all algorithms of multidimensional dispersional analysis can be found in Tou and Gonzales (1974) and in Ahrens and Läuter (1981). The CORA-3 algorithm is widely applied in the problems of an earthquake prone area recognition and its description is given e.g. in Gelfand et al. (1976) or in Cisternas et al. (1985).

1. In a general case there are J ($J \geqslant 2$) classes of objects. The vectors of observations with dimension p corresponding to the j-th class ($j=1,2,\ldots,J$) must have normal distribution $N(\bar{\mu}_j, \sum)$, where $\bar{\mu}_j$ is the vector of mean values for the j-th class and $\sum$ is covariational matrix which is common for all classes. Vectors μ_j and matrix $\sum$ are usually unknown.

It is supposed that for each class exist $n_j \geqslant 1$ observations and $n=\sum_{j=1}^{J} n_j$, where $n_j \geqslant p+J+2$. The vectors of parameters of an object are denoted by

$$\bar{y}_{jk} = \begin{pmatrix} y_{1jk} \\ y_{2jk} \\ \cdots \\ y_{pjk} \end{pmatrix} \qquad (j = 1,..,J;\ k = 1,..,n) \quad .$$

In our study J=3 and objects are the vectors of the parameters of accelerograms. A one-factor classification is performed: the objects are divided into classes according to the influence of the one factor (macroseismic intensity).

2. The considerations for a statistical analysis are based on the estimates of

(i) vectors of means of individual classes

$$\bar{y}_{j*} = \frac{1}{n_j} \sum_{k=1}^{n_j} \bar{y}_{jk} \qquad (j = 1,\dots,J) \quad ;$$

(ii) means of all classes (total mean value)

$$\bar{y}_{**} = \frac{1}{n} \sum_{j=1}^{J} n_j \, \bar{y}_{j*} \quad ;$$

(iii) covariation matrixes of individual classes

$$S_j = \frac{1}{n_j-1} \sum_{k=1}^{n_j} (\bar{y}_{jk} - \bar{y}_{j*})(\bar{y}_{jk} - \bar{y}_{j*})^T \qquad (j = 1,\dots,J) \quad ,$$

(iv) mean covariation matrix

$$S = \| S_{hi} \| = \frac{1}{n-J} \sum_{j=1}^{J} (n_j - 1) \, S_j \quad ,$$

(v) "a priori" probabilities of classes

$$p_j = \frac{1}{n_j} \qquad (j = 1,\dots,J) \quad .$$

Vectors $\bar{y}_{j*}$ and matrix S are unbiased estimates of $\bar{\mu}_j$ and $\sum$. The elements of the correlation matrix R

$$r_{hi} = \frac{S_{hi}}{S_{hh} \, S_{ii}} \quad .$$

3. The statistical model

$$\bar{y}_{jk} = \bar{\mu}_j + \varepsilon_{jk} \qquad (j = 1,\dots,J;\ k = 1,\dots,n),$$

where ε_{jk} are normally distributed deviations from the "average" accelerogram of the given class, permits us

(i) to test the hypothesis about the equality of all vectors of means

$$H_o : \bar{\mu}_1 = \bar{\mu}_2 = \dots = \bar{\mu}_J \quad ,$$

(ii) to make a comparison of the means vectors in pairs, i.e. to test the hypothesis

$$H_{ij} \; : \; \bar{\mu}_i = \bar{\mu}_j \qquad (i \neq j) \qquad ,$$

(iii) to estimate the individual ability of an arbitrary set of parameters (multidimensional distance), in particular of all parameters $y_1, \ldots, y_p$

$$\text{"distance"} : \; T^2(y_1, \ldots, y_p) = \frac{1}{n-J} \sum_{j=1}^{J} n_j \cdot$$

$$\cdot (\bar{y}_{j*} - \bar{y}_{**})^T S^{-1} (\bar{y}_{j*} - \bar{y}_{**})$$

and of each parameter y_i

$$\text{"distance"} : \; T^2(y_i) = \frac{1}{(n-J)S_{ii}} \sum_{j=1}^{J} n_j \cdot$$

$$\cdot (y_{ij*} - y_{i**})^2 \qquad .$$

This measure of ability is monotonous with respect to the expansion of a set of parameters and is invariant under linear non-degenerate transformations of the set.

4. Finally, within the limits of this statistical model we can carry out a one-factor classification (clusterization) of observations by mean of a minimum of values of J discriminant functions (distances to the centres of the corresponding classes). We used the following distances from the classified vector $\bar{y}$ to the centre of the j-th class $\bar{y}_{j*}$:

(i) the Mahalanobis distance

$$m_{MAH,j} = (\bar{y} - \bar{y}_{j*})^T S^{-1} (\bar{y} - \bar{y}_{j*}) \qquad ,$$

(ii) the estimate of F-statistics with p and $n-J-p+1$ degrees of freedom

$$m_{FACT,j} = \frac{n-J-p+1}{p\,(n-J)} \cdot \frac{n_j}{n_j+1} \, m_{MAH,j} \qquad ,$$

this estimate allows the confidence level of the classification to be verified,

(iii) the estimate with regard to "a priori" probabilities of classes

$$m_{APR,j} = m_{MAH,j} - \log p_j \qquad ,$$

(iv) the estimate with regard to different covariations in classes

$$m_{DCOR,j} = (\bar{y} - \bar{y}_{j*})^T S^{-1} (\bar{y} - \bar{y}_{j*}) - \frac{1}{2} \log \det (S_j)$$

(v) the estimate with regard to all these possible distinctions between classes

$$m_{DAPR,j} = m_{DCOR,j} - \log p_j \quad .$$

Each algorithm works in the following way : we calculate the corresponding distances from the given object to the mean vectors of classes and then attribute it to the class with the minimum value of the distance to its centre.

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EARTHQUAKE CATALOGUES AND HAZARD ASSESSMENT

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1. Introduction

The present paper reviews various aspects of seismological inputs and their influence on accuracy of hazard assessments because "producers" as well as "users" become more and more concerned with uncertainties and inconsistencies in results provided by different expert groups. These uncertainties can be caused either by poor inputs or by inadequate methodologies or by both. The third kind of uncertainties is introduced by differenc es in personal judgement which still replaces well defined procedures at certain stages. The presently adopted terminology defines seismic hazard as the probability P of occurrence of a potentially damaging ground motion of intensity i at a particular site during a certain time interval.

The basic steps of seismic hazard calculation are:

A. definition of earthquake source regions, i.e. principally the estimate of future earthquake activity within defined boundaries
B. propagation of strong ground motion, including site specific effects (microzoning),
C. development of adequate algorithms for hazard calculation, i.e. adoption of a probabilistic model.

Our review will deal mainly with the first step and partly the second one.

2. Catalogues

Catalogues, as basic seismological inputs, should be homogeneous in time and space as well as uniform in determination of individual parameters. It means that a catalogue cannot originate by simple collection of information from different sources without critical unification. Following examples of formats of recent catalogues compiled on national, regional or global scales give an idea on existing standards.

Format proposed in the UNESCO sponsored study for the Global Seismic Data Bank in 1980 [1] suggests these parameters for inclusion in the basic file : date, origin time, geographic co-ordinates depth, magnitude (surface wave magnitude, body wave magnitude, local magnitude), epicentral intensity, radius of isoseismal, i.e.

both instrumental and macroseismic, and references (station, bulletins, isoseismal maps, monographs, report). All parameters are accompanied by quality factors. The format is supposed to serve research tasks as well as applications. Several sublists providing additional information have been suggested (source parameters, fault plane solution etc.). This UNESCO project has never been implemented because of lack of funds. Many potential users were interested but only very few were ready to contribute financially.

What is actually available for the European area? On the global scale the Catalogue by Gutenberg and Richter [2] covering the first half of the 20th century remains still very useful because of uniform magnitude determination, however, it is complete only above M = 7. The more recent document is the global catalogue by Abe [3], complete above M = 6 3/4 for the period 1904-1980. The other global source is the International Seismological Summary which is, however, lacking information on the size of events. It contains only origin times and hypocentre coordinates with travel times of P and other phases, and is therefore not usuable for seismicity and statistical studies. The bulletins of the International Seismological Centre (ISC) issued since 1963 with more advanced procedures of parameter determination fulfil already much wider requirements of users.

Unfortunately, for many years only body wave magnitudes m_B (short period PV waves) were used for size classification of events and the users must be aware of the limitations of this scale which saturates at about M = 6 1/2 [4]. Therefore m_B values are not suitable for statistical studies involving large events.

Since 1981 the bulletins (catalogues) of ISC and of NEIS contain regularly surface wave magnitudes M_S based on vertical component of Rayleigh waves, i.e. the situation in the domain of large events has been improved. More recently parameters of fault plane solutions determined in a standard way are published by both agencies. Moreover ISC publishes since 1976 a special annual issue on felt and damaging earthquakes which provides macroseismic and other information relevant to risk assessments.

Whether we like magnitude or not it is still the only quantity which defines the size of the event in an objective way. It can be routinely determined and is available for large sets of earthquakes. More advanced and better defined quantities like seismic moment or stress drop are available only recently for very limited number of events.

It is, however, imperative that every catalogue contains clear-ly defined magnitudes for all catalogued events, preferably one type (scale), e.g. local magnitude M_L or M_S. If several magnitude scales are used in one catalogue, which is often unavoidable, they mus be mutually linked by conversion formulae and all scales must be calibrated in a uniform way. Misleading results can be obtained if e.g. earthquakes classified by m_B, M_L, M_S are mixed together and a magnitude-frequency graph is compiled. Naturally, negative consequencies of heterogeneous classification can be reflected in other results. It is why all parameters in spite of the time needed for such work. Neglecting this principle leads only to poor outputs.

On the European scale good national and regional catalogues have been prepared during the last two decades, evidently also under the pressure of practical requirements for a sound hazard analysis. At present every country of the European area has an up-dated earthquake catalogue containing basic parameters, i.e. origin time, epicentre coordinates, magnitudes and macroseismic information. For th large part of the territory (Central and Eastern Europe, the Balkan Italy, Spain, Portugal, Algeria, Great Britain) Atlases of Isoseismal Maps have been published as well.

The last version of the catalogue compiled for Italy [5] by an expert group with Postpischl as chief editor is a typical example of a national catalogue.

The USSR catalogue of strong earthquakes [6] which is remarkable by the serious attempt to indicate the accuracy of parameters by estimates of errors, the catalogue is also interesting by giving different types of magnitudes and all known mean radii of isoseismals. It is noteworthy that USSR publishes annual summaries of information on strong as well as weak earthquakes with all maps and statistics. These publications complete the basic catalogue. Such a system of up-dating catalogues published earlier should become a practice of European seismological services.

The European catalogue 1901-1955 [7] by Kárník has the same lay-out which was used for the UNESCO Balkan catalogue 1901-1970 [8]. All magnitudes have been uniformly determined.

It must be emphasized that European seismologists benefit for years from the services of the European-Mediterranean Seismological Centre (EMSC) in Strasbourg which is carrying out a rapid epicentre determination and publishes bulletins of earthquake parameters including all available magnitude determinations. This information appears later in ISC summaries.

The outputs of Seismological centres are of great help in compiling catalogues from the last one or two decades because of uniformity in parameter determination, however, a national catalogue must contain more information than a centre can provide. The amount of this additional work is decreasing with expanding and improving activities of centres.

For hazard assessments, however, much longer time span of observation is needed than one or two decades. Thus the main difficulty for a seismologist is to collect and unify information from the whole historical period. It must be emphasized that one should not be satisfied with what is easily found in publications describing historical events. They contain often information which was transcribed several times, one author copied it from the other, and in this way misprints, errors and translation mistakes originated. It is highly desirable, although again it is a tedious and time consuming work, to search in original documents written preferably by contemporary observers. This is still a rewarding effort which brings new data and eliminates serious mistakes. Examples of such succesful efforts are the detailed studies of the largest historical events compiled in Spain, Italy, Austria, Iran, Hungary and in other countries. For this activity the involvement of historians is necessary. The work of Ambraseys and Melville on Persia [9] can serve as an example of this type of work.

The problem of depth of focus in the catalogues might be mentioned. Undoubtedly, this parameter is significant, however, only very dense station networks can guarantee a reliable depth determination. Thus for a majority of events the instrumental depth determination remains questionable, particularly in the range of depths down to 50-60 km, i.e. in the domain of "normal" or "shallow" earthquakes. Deep phases pP and sP permit already the depth determination for deeper shocks, i.e. the catalogues are more reliable for intermediate and deep events. The comparison of magnitudes and intensities or the analysis of intensity attenuation can help to estimate at least approximately, the focal depth. Examples of such efforts are in the European, Balkan, USSR and other catalogues. However, the uncertainties remain and are being removed only slowly by increasing density of stations.

Macroseismic information is included in every catalogue, at least epicentral or maximum observed intensity is given. It is advisable to add, whenever possible, the radius of the shaken area and one or two radii of isoseismals, r_5 and r_3 were recommended as standards. Isoseismal maps are still the main source of information on attenuation if intensity is the quantity defining hazard. The isoseismals can also control substantial regional differenc es in attenuation. The application of one macroseismic scale throughout the catalogue is necessary. Even if different sources indicate e.g. that MCS scale was used, it is advisable to check the values by studying original reports on macroseismic effects. There are too many examples of very personal use of a scale so that differences between two individual authors can easily reach two grades.

It is also advisable to recompute epicentre coordinates or at least to check them when using agency´s data from the first half of this century when density and distribution of stations was inadequate. Frequently, so called macroseismic epicentres are more reluable than the instrumental ones from the above mentioned period.

The last item worth mentioning is the classification of accuracy of catalogued parameters. There is no simple recepee for that if a long observation period is covered. Anyway this information either in the form of standard error or by introducing classes should be an integral part of each catalogue.

Earthquake parameters are catalogued with the tendency to define each event as fully as possible. Principal source parameters relate to the position of the source and to the size of the event. In addition, quantities defining the orientation of the fault plane and type of the movement are given, these quantities can be determined on a routine basis only for larger events of $M>6$. Processing of digitized records permits now to calculate several dynamic focal parameters like seismic moment, stress drop, the length of the fracture. Phenomena accompanying larger shocks are also of importance, e.g. tsunami observations, local macroseismic intensities, material damage, number of victims or injuries, volcanic activity, behaviour of animals etc. In general, the number of available parameters and their accuracy are increasing with time.

3. Uncertainties on hazard assessments

Everybody compiling seismic zoning and hazard maps realizes soon that there is a great deal of uncertainty in each step of the procedure which is predominantly probabilistic but includes also some deterministic steps, e.g. in delineating source regions, in estimating M_{max}, and others all authors and users should be aware of the weaknesses of the current methodology. The uncertainties can be taken into account in a probabilistic approach which has been recently introduced and accepted by engineers, planners and regulatory bodies.

The sources of uncertainties are mainly (see Table) :

i) poor inputs or the lack of some observational data on earthquake generation and seismic energy propagation,

ii) the inadequate models of earthquake sources, of distribution of events in time (the models oversimplify the reality) and of local effects on attenuation of ground motion,

iii) personal judgement of experts, diversity of experts opinion.

The basic source of uncertainties is in the definition of source regions. This step comprises :

1) the delineation of the boundary of the volume where earthquakes are expected to occur in the future and their origin is supposed to be governed by one mechanism of generating forces,

2) the definition of the model of earthquake activity in the region using the magnitude-frequency relationship, eventually defining the limits and periods (if possible) of the time variation of activity and of its spatial migration,

3) determination of the largest possible event for different time intervals.

Boundaries of the source regions divide usually concetrations of hypocentres aligned along fault zones or grouped in clusters. Areas outside these concentration are sometimes classified as aseismic. If the observation period is short such conclusions are premature and may result in so called "seismological surprises" when a strong event suddenly occurs in a low seismicity zone. This experience calls for the observation periods as long as possible and for delineation based also on neotectonic and geophysical evidence.

In areas of medium and low seismicity the small numbers of events gives too much freedom in drawing boundaries of source regions and different configurations may originate, see examples from Central Europe, Czechoslovakia [10] and GDR [11]. Consequently, assigned activity levels, and the hazard at a particular site within or outside the area are influenced by the configurations. The variation of hazard due to boundaries of source region can be estimated only by studying two specific version as done by Rast and Saegesser in Southwest Germany and Northern Switzerland.

The hazard varies within 0.5 to 0.7 of intensity grade in this particular case [12].

The quality of catalogued information influences most the definition of the activity model. The simplest and mostly used approach is the determination of the magnitude-frequency relationship log N(M) = a - b M. In principle a corresponds to the level of activity and b defines the ratio between strong and weak events. For evident reasons the distribution must be trucated at both sides by M_{min}, M_{max} where the latter quantity predestines extreme hazard values. The relationship is entirely dependent on the data set from the catalogue. It is recommended to have at least 100 events for a sound N(M) determination.

Table
Uncertainties in hazard assesments

Source	Consequences
Short observation period covered by the catalogue	Extreme events may be missed, boundaries of source regions wrongly delineated, N(M) not representative, may cover either an active or a quiet period
Different magnitudes without unification	Large scatter in N(M), N(M) questionable
Use of m_B (short-period PV)	saturation at M= 6 1/2, bending of N(m), loss of distinction between large events, N(m) not usable for hazard assessment
Mean radii of isoseismals in site evaluation (instead of azimutal attenuation)	errors in hazard values within $\pm$ 1° or more
Different expert delineation of boundaries of source zones	errors up to $\pm$ 1° in hazard
Error in M_{max}	1/2 magn. unit results in 100% change of hazard values (the largest effect)
Doubling activity rate	acceleration increases by about a third

The second requirement is uniformity of magnitudes for reasons discussed earlier. The obtained relationship corresponds to a certain time interval and to mean activity changes with time in periods which vary from region to region. If the observation period is only few decades the sample may correspond either to a period of increased activity or of quiescence. Then the use of resulting N(M) may substantially underestimate or overestimate the future hazard.

The lack of data within the low magnitude range may lead to an artificial decreases of b if the data are used without a proper checking. This change may increase the estimated number of large events and thus the hazard itself.

Unfortunately, although it is almost always impossible to choose the maximum magnitude from the statistics of the historical seismicity, maximum magnitude is generally the most important of the parameters, in terms of its imapct on the hazard. This is particularly true in regions of low seismicity, where maximum observed magnitudes are low.

According to Perkins, Bender and Shedlock [13] for low maximximum magnitudes, around 4 or 5, increasing maximum magnitude by one unit will double the ground motion at a given return period. For point source models, the factor increase of acceleration decreases with increasing maximum magnitude, and for magnitude greater than 7, the increase is not very important for high b values. However, for low b-values, which are to be expected in active zones, and especially for finite rupture models, regardless of b-value, increasing maximum magnitude always produces significant increases in mapped ground motion. b-values have a somewhat lesser effect on probabilistic ground motion. Changing a b-value by 0.1 is roughly equivalent to changing the return period for a given acceleration by about a factor of 2 or 3. The probabilistic ground motion values from rupture source models may differ by as much as 15 percent for different formulae used for relating average rupture length and magnitude.

N(M) distribution can exceptionally indicate itself the threshold value M_{max} for a very long observation period in an active region. The bending of the end of distribution may be misleading because it may simply reflect the saturation of the magnitude scale, this effect must be carefully checked as well as any deviation of (log N(M)) from linearity, e.g. the deficit of observations in some magnitude classes.

The faith in numbers produced by hazard assessments is great among users who have no sufficient knowledge of all uncertainties involved and it is the duty of researchers to complete the numbers with evaluation of errors and, eventually, of diversity in expert's opinion. It is evident that under the present state-of-the-art hazard assessments provide only orientational numbers which can guide the users, however, cannot be relied upon as exact values.

It is noteworthy that the Lawrence Livermoore National Laboratory in the USA in 1986 checked the scatter of results caused by diversity of professional judgement of sixteen experts on the example of hazard assessment for ten sample sites in the esatern U.S. Thus a clear distinction has been made between the random variation in the input information (earthquake rate, ground motion) and the uncertainties due to diverse opinions between experts. Modelling uncertainties were introduced into the estimation processes by having the experts provide alternative zonation model as well as ranges for different parameters. It can be concluded that the uncertainty introduced by the diversity of opinions is of the same order, on the average, as the uncertainty in the hazard due to differences between individual experts in the value of some parameters. Thus the inter-expert variation contributes substantially to the overall uncertainty in hazard estimate.

4. Conclusion

The capability to create statistical and analytical models is far ahead of the data required to validate the models. It underlines the basic problem we wanted to illustrate in the contribution, i.e. that the succes in hazard assessment depends mainly on the experimental inputs, i.e. on controlled and uniform sets of earthquake parameters covering a time interval, as long as possible. Theoretical models and probabilistic methods can help us to organize the data and to introduce certain system in the processing, however, they cannot add something new to the observations.

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IMPACT OF STORM MICROSEISM VIBRATIONS ON THE EARTHQUAKES OF THE KURILE-OCHOTSK REGION

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Storm microseismic vibrations (SMS) recorded in the Pacific Ocean at the outer curve of Kuril islands are compared with earthquakes having occured in the same region. SMS power (10^4 - 10^8 J/s) and energy (10^9 -10^{13} J) which depend on intensity and duration of storms are estimated. These values are comparable with energy of small and medium earthquakes of the Kuril region.

Fig. 1 (not shown) presents SMS intensity values (ΣI) monthly (a solid line) and the number pf earthquakes with energy 10^9 -10^{13} J (the data of 1968-1982). The number of earthquakes with hypocenters at the depth of $h \geq 30$km (a dashed line) and $h \geq 20$km (a dashed-dotted line) are indicated as $\Sigma\tilde{N}(30)$ and $\Sigma N(20)$ respectively. Curve of ΣI SMS and $\Sigma N(30)$ of the earthquakes are in opposite phase. They have cross correlation coefficients ç(30)=0.597,ç(20)=-0.674, while for depths of $h \leq 200$km ç=-0.41. Correlation coefficients increase with shift of ΣN curves relative to ΣI curves by the time interval equal to one month: ç(30)´=0.702,ç(20)´=0.61 and ç(30)´=-0.701. For the earthquakes with power 10^{11}-10^{13} J and $h \leq 200$km relationsships with storms is considerably lower (ç(30)=-0.355, ç(20)=-0.55). For the earthquakes of great powers the relations with storms are not observed. The increase of correlation coefficients with the curve shift may be accouted for by coincidence of ΣI maximum and ΣN minimum, while naturally ΣI maximum leads minimum. Storms of medium intensity, never reaching maximum, are likely to bring down stresses and decrease the number of earthquakes. SMS vibrations lessen friction with subduction of oceanic plate in the region of Kuril islands at a depth of 20-30km.

LONG-PERIOD SPECTRAL LINES OF MICROSEISMS RECORDED AT KEVO

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Microseismic studies using the digital data of Kevo DWWSSN-station have been in progress since 1983. Main subjects of these studies have been the noise level, polarization properties, direction of approach and identification of source areas.
The microseismic studies have since last years focused the main interest in two strong principal period ranges. The digital sampling technique and effective spectral analysis methods have revealed periods beyond 20 seconds.
This paper presents the spectral peaks, found via direct spectral computing method (Cooley & al. 1970), at periods from circa 25 seconds up to 36 seconds. Spectral windows from 1024 to 2048 and up to 10 non-overlapping blocks were used in analysis. Direction of approach of microseisms was estimated by the cross spectral method (Haubrich & al. 1969, Holcomb 1980). This method utilizes the possibility to estimate the purity of signal through the coherency function of the spectral and cross spectral densities of the 3-component registrations. The coherency is near unity, when signal is approaching the station as a narrow beam, otherwise the value decreases and is zero when the signal is isotropic in nature.
In this paper a storm having long-period microseismic peaks is studied. This storm began around 08th October 1985 and lasted approximately 10 days. The most significant spectral peaks are shown in figure 1, where two prominent peaks at 23 and 36 seconds are visible. Direction analysis gives for the direction of approach values of 242 degrees for the 23 second's peak and 232 degrees for 36 second's peak. The coherencies for these peaks are 0.34 and 0.35 respectively. These are not very high values of coherency, but one can point out that after meteorological situation over northern Europe there are numerous effective weather disturbancies. The possible source areas of the longer waves may be located at great sea-areas at great distances, for example the African coast is one potential source area. Naturally these long-period waves may be caused by strong local winds (Savino & al. 1972).

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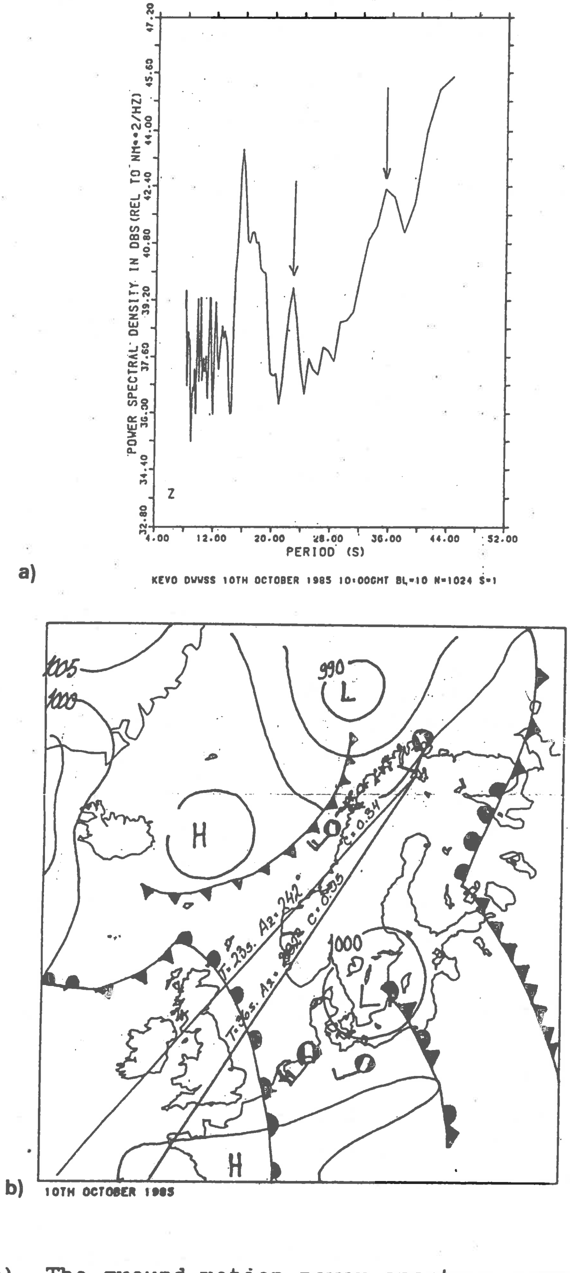

Fig. 1 a) The ground motion power spectrum computed from the registration of Kevo DWWSSN-station 10th October 1985 starting 10:00GMT. In computations 10 non-overlapping blocks of 1024 samples were used. b) the meteorological situation at the same day at 08:00GMT and the directions of the two strong-period spectral peaks shown in the uppermost figure.

SEISMIC ACTIVITY IN THE REGION OF OPENCAST MINES OF THE NORTH BOHEMIAN BROWN-COAL DISTRICT

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1. Introduction

In connection with the planned opencast mining in the North Bohemian brown-coal district in the deep opencasts at the foot of the Krušné hory Mts., increased attention is being paid to observing the seismic activity in this region. In the next years the original mountain slopes are going to be exposed to a depth of 100 - 150 m in the Czechoslovak Army Giant Opencast; in the other opencasts the stripping depth is going to attain 200 - 300 m. An adverse effect of seismic waves on the stability of temporarily weakened mountain slopes and the origin of landslides or slope collapses of a great extent cannot be precluded. Local earthquakes may be the potential source of intensive seismic waves (Procházková et al., in press - a).

In investigating the seismic activity, we limited ourselves to the Most and Chomutov parts of the basin, where most of the opencasts are situated, and to the adjoining part of the Krušné hory Mts. (Fig. 1). Earthquake foci are distributed in an area of about 18 km x 20 km. Observations of 44 earthquakes are available from the period 1784 - 1910. All the earthquakes were shallow with depths up to 10 km and with epicentral intensities ranging from 3° to 6.5° MSK-64. In Fig. 1 the foci are numbered in the time sequence, the foci close in place and time being given under one number. This focal region is separated from the nearest focal region in West Bohemia and in the Vogtland by an area devoid of any seismic activity and we will deal with it as an independent whole with its own seismotectonic regime.

Historical data allow the determination of the seismic hazard for this region. Since the year 1910, however, no macroseismic observations have been made in this region and very low seismic activity have been observed in the domain of microearthquakes only. In the present contribution, the connection of microearthquakes with macroseismically observed shocks is studied on the basis of magnitude-frequency relations.

2. Macroseismic observations

To determine the seismic hazard, we shall apply the formulae used for the computation of earthquake recurrence in the region of the Belchatow coal mine in Poland (Gibowicz and Kijko, 1984; Kijko 1985). The probability of an earthquake occurrence with magnitude M that is not smaller than M_i, in time t, is

$$(1) \qquad R_t(M \geqq M_i) = 1 - \{\tau/[\tau + t\, P(M \geqq M_i)]\}^{n+1},$$

where τ is the time of observing seismic activity, n is the number of all observed earthquakes and

$$(2) \qquad P(M \geqq M_i) = [\exp(-\beta M_i) - \exp(-\beta M_{max})]/ /[\exp(-\beta M_{min}) - \exp(-\beta M_{max})].$$

M_{min} denotes a minimum magnitude, from which on an earthquake catalogue is complete, i.e. it gives the limit of the material homogeneity, M_{max} is the magnitude of the maximum possible earthquake in a particular region, $M_{min} \leqq M_i \leqq M_{max}$. Parameter β = b ln 10, where b is the coefficient from the magnitude-frequency relation log N = a - bM and N is the cumulative frequency.

The catalogue of earthquakes contains a total of 43 earthquakes with known intensities in the study region from the years 1784 - 1910 (Procházková et al., in press - a). In the present contribution we consider observation time τ = 200 years even though since the year 1910 there have been no other earthquakes documented macroseismically. Epicentral intensities I_0 were transferred to magnitude values by means of the relation valid for the Bohemian Massif: M = 0.63 I_0 + 0.5. Thus for the minimum observed intensity we get M_{min} = 2.4, and M = 4.6 corresponds to the maximum epicentral intensity 6.5°. We derive the coefficients of the magnitude-frequency relation for magnitude classes M_i beginning with the minimum magnitude value 2.4, and the class range corresponding to 1°, i.e. ΔM = 0.6. The cumulative frequency value is always related to the class centres, which in our case are 2.4, 3.0, 3.6, 4.2 and 4.8. For a set thus classified, we derived values b = 0.674, a = 3.269 (the correlation coefficient is -0.999), β = 1.55. With respect to the upper limit of the largest magnitude class, we take $M_{max} = 4.8 + \Delta M/2 = 5.1$. This value roughly coincides with the magnitude for the intensity of the strongest observed earthquake increased by 1^{o}.

Table 1 presents the computed seismic hazard for the above parameters. Low seismic activity also suggests little probability of earthquake origin. Even if we take into account the weakest earthquakes within the limits of macroseismic observations with $M_i = 2.4$, for observation time of 5 years we get R = 0.67 and only for the observation interval of 50 years R = 1. Not until 1000 years of observation R = 0.67 for maximum magnitude $M_i = 4.8$.

The mean return period T defined by the equality T = t for R = 0.633 is given in Tab. 2. The cumulative frequency of N earthquakes with magnitudes $M \geqq M_i$

$$(3) \qquad N = \tau / T,$$

is compared here with the cumulative frequencies observed. A very good accord confirms the agreement of the observed values with the computed ones according to the general magnitude-frequency relation. In the particular area, a cycle of stress compensation is likely to have occurred at a given time, and in the respective magnitude range observations are neither missing nor redundant. It has to be noted that it is a narrow interval of earthquake magnitudes (2.4 of a magnitude unit).

Assuming the active period in a given magnitude range terminated in the year 1910, we could shorten the observation time τ = 200 years to τ' = 126 years. From (1) and (2) it follows that for the same M_i value R will not change for the time interval t'

$$(4) \qquad t' = t\,\tau'/\tau,$$

and therefore the mean return periods T' will be given by relation

$$(5) \qquad T' = T\,\tau'/\tau\ .$$

The cumulative frequencies determined according to equality (3) will not change.

The above assessment of seismic hazard corresponds to the least favourable conditions since it starts from the assumption that earthquakes with a particular magnitude-frequency distribution may occur in an arbitrary place of the area. Other assessments take the position of foci as invariable and consider a loss in the earthquake intensity with distance. Our case involves distances of 20 km at most, in which the usually maximum intensity decay is 1° MSK-64 (Procházková, 1985).

3. Microseismic observations

To estimate the possibility of recording microearthquakes in the region under study within a reasonable time period of several years, we calculated the probability of the origin of shocks from $M_i \geqq 0.6$. The real magnitude-frequency relation was extended by magnitude classes 0.6, 1.2 and 1.8, and the number of earthquakes N was determined by extrapolation. Supposing the other parameters needed for the calculation to be invariable, we obtained the values presented in Tab. 3. The table gives the respective probabilities that for $M_i = 0.6$ promise the possibility of recording microearthquakes in the course of annual measurements. The minimum value M = 0.6 was selected deliberately; in accordance with Tobyáš et al., 1985, earthquakes with magnitude $M \geqq 0.5$ can be detected in this region by the two nearest seismological stations (the local station and the Berggiesshübel station in GDR).

For a comparison, Fig. 2 shows the probabilities of the origin of both macro- and microearthquakes.

In observing the present seismic activity, we have to solve successively the following problems:

(i) localization of seismic events in the region,

(ii) discrimination tectonic earthquakes and man-made seismic events,

(iii) determination of tectonic earthquakes magnitudes.

In this paper we shall present the methods of solving the individual problems and the results obtained during the four-year period of 1982 - 1985.

(i) For the purposes of localization we made use of the network of the nearest seismological stations equipped with highly sensitive seismographs; the possibilities of localization were tested first for the whole territory of the CSR (Knaislová et al., in press), and second, for the mining region in NW Bohemia (Procházková et al., 1985; Tobyáš et al., in press - a). The localization is directed at a larger area than the focal region and the area of opencast mines; it is delimited by geographical latitudes 50.3° - 50.65° N and geographical longitudes 13.1° - 13.8° E. On the territory of the CSR it has become a practice to apply data of local station Vysoká Pec (VP) and of stations Průhonice (PRU) and Kašperské Hory (KHC), in the GDR of station Berggiesshübel (BRG), and in Poland of station Ksiaz (KSP).

Table 4 contains a survey of the number of recorded shocks in individual years. In the domain of weak seismic events, the 1982 data are influenced by the fact that the local station had only been operating for 3 months. Among the localized shocks are also those that were recorded by only two stations and both foci lie in the study region. Among the detected shocks are given those recorded by the local station only. If it was possible to determine the distance from the difference of the arrival time of a P and S wave, only the shocks whose epicentral distance was up to 30 km were included into the list. The shocks with only S waves recorded were comprised into the region if a local event could be inferred from the time duration of the event record (time duration less than 8 - 10 s).

(ii) We are unable to distinguish reliably tectonic shocks from man-made ones according to analogue seismograms. Therefore in Tab. 4 as tectonic shocks are denoted only those that were recorded during the night hours when industrial blasting is not made (in the period of the summer time it is between 9 p.m. and 4 a.m., in the period of the winter time between 8 p.m. and 5 a.m.). To man-made sources we attribute shocks on the basis of coinciding time of an announced blast ± 0.5 h., and of other features (distance, focus position, magnitude with respect to the explosive charge volume). The remaining shocks recorded in the day-time are classified as shocks of an unknown source. Among them are blasts (e.g. in the year 1985, neither the local station recorded some 124 blasts at the times reported from opencasts), probable tectonic shocks, and possibly also shocks induced by blasts of a great extent.

Throughout the measurement time, tectonic shocks were recorded by at least three stations in 8 cases only, and by two stations in 25 cases. Most tectonic shocks were still weaker so that they were only recorded by the local station.

Localized foci are demonstrated in Fig.3. Neither the positions of epicentres, nor the positions of known faults are sufficiently accurate for us to associate individual foci with particular faults. This refers not only to the lesser fault tectonics of the Krušné hory Mts., but also to the master fault of the Krušné hory Mts. (Kopecký et al., 1985). The foci in the basin might be connected with the Krušné hory Mts. fault, which inclines obliquely to the basin. Moreover, the foci line roughly perpendicularly to the Krušné hory Mts. fault between Most and Hora Svaté Kateřiny. This case presents a connection with the Jezeří - Ryzel range. These are of course only hypotheses starting from the assumption that the earthquake foci really lie in the basin and that the other solution of the localization with foci in the Krušné hory Mts., denoted by full circles in Fig.3, is not valid. An unambiguous determination of focus positions is impossible without another seismological station being installed in the region.

At first glance it is striking that in the east margin of the area with the focus of the strongest earthquake in the region, foci of tectonic microearthquakes are missing.

For a comparison with tectonic shocks foci Fig.4 contains foci of the seismic events recorded in the years 1982 - 1985 in the day-time that were not classified as due to the known blasts. Most of them can be found outside the basin.

(iii) The majority of tectonic shocks were only recorded by the local seismological station and station Berggiesshübel. For this reason, the magnitude relations derived for stations PRU and KHC (Procházková et al., in press - b) could not be applied, and it was necessary to derive magnitude relations at least for station BRG.

In view of the recorded phases and their reliability, the local magnitude M_L is determined on the basis of the time duration τ of the vertical component of the entire shock record, and on the basis of amplitude A and the period T of the maximum phase of the Lg wave according to the following relations (Mittag and Tobyáš, 1985)

(6) $$M_L(\tau) = 0.190 + 1.446 \log\tau + 0.00191\Delta ,$$

(7) $$M_L(Lg) = \log(A/T) - 0.00015\Delta + 1.97 .$$

Epicentral distance Δ is in kilometres, A in nanometres, τ , T in seconds. The local magnitude value is then converted into magnitude M consistent with the surface wave magnitude scale with the aid of approximate relation (Tobyáš et al., in press-b)

(8) $$M = 1.36\ M_L - 2.9\ .$$

So far the magnitudes of tectonic microearthquakes of 1982-1985 have been determined. According to (6) the values come under magnitude classes 0, 0.6 and 1.2. According to (7) the magnitude values are systematically greater by about 0.9 and belong to classes 1.2, 1.8 and 2.4. The discrepancy between both relations should be subjected to special analysis. The cumulative frequencies of microearthquakes in 39 months were recalculated for the period of one year and they are presented in Tab.5 together with the values of mean magnitudes from (6) and (7). For the same magnitude range we calculated the mean return periods T and the cumulative frequency in a year N_y

(9) $$N_y = 1/T$$

for a period of 200 years.

Figure 5 illustrates annual cumulative frequencies in the domain of macroseismic observations compared with microseismic ones. Annual cumulative frequencies in the range of magnitude classes 2.4 - 4.8 for periods of 200 and 126 years are extrapolated up to value M = 0 in a dashed line. The cumulative frequencies of observed microearthquakes for both magnitude relations and the mean magnitudes are divided into three magnitude classes. The smallest magnitude class has invariably a shortage of shocks, which may, of course, find themselves among the weakest tectonic shocks detected by the local station only. The other two classes satisfy the general regularity, namely that the number of shocks grows with the decreasing magnitude. The slope of the magnitude-frequency graph is greater than with strong shocks. The absolute level of annual frequencies is of the order of extrapolated values. This finding is rather surprising since in 39 months natural regularities are beginning to assert themselves in the data set despite all the difficulties in obtaining and processing the data and the very low recent seismic activity.

Some more tectonic shocks are likely to have been recorded even in the day-time and are included among the shocks with an unknown source. There are a lot of these shocks - 2702 in the years 1982 - 1985; provided tectonic energy is uniformly released with time, the number of tectonic events in the day-time would be 66. The numbers of tectonic microearthquakes in individual years (1982 - 4 during 3 months, 1983 - 2, 1984 - 14, 1985 - 13) as well as the identified swarm character of detected microearthquakes with a time duration from several hours to several days testify against the use of mean values in extrapolations. Also the occurrence of macroseismic events had not been equably distributed in time: 21 events were observed during the day-time and 20 events in the night.

4. Conclusions

Until now the macroseismic activity in the delimitated area of the region of the North Bohemian brown-coal district has been generally simple; there have occurred a few separate shocks and one earthquake swarm. The probability distribution of macroseismic data accords with general presumptions and gives a certain idea of the pattern of tectonic energy release in the past. We started from a simple assumption that also the present microseismic activity is affected by a simple stress field and the magnitude-frequency relations of both events very different in energy link up. The established cumulative frequencies of microearthquakes determined from an interval of observations of 3 1/4 years are in good agreement with the values extrapolated from macroseismic data.

In comparison with the map of seismic hazard for the CSR (Kárník et al., 1984), in the particular area we get higher earthquake intensities for the return periods. According to the paper quoted, e.g. for a return period of 100 years, intensity $I = 4.4^{\circ} - 4.7^{\circ}$ is attained in the study area. From the graph in Fig.2 of the present work we get for the same return period ($t = 100$ years, $R = 0.633$) the magnitude of the local earthquake $M = 4.2$, i.e. epicentral intensity $I_0 = 5.9^{\circ}$. Likewise, for an extremely long return period of 10000 years $I = 6.3^{\circ} - 6.7^{\circ}$ in the region according to the above mentioned paper, whereas our estimate gives magnitude $M = 4.8$ and thus $I_0 = 6.8^{\circ}$ for a return period of 500 years.

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Table 1. Probability of earthquake occurrence with $M \geq M_i$ during time interval t.

t (Years)	M_i 2.4	3.0	3.6	4.2	4.8
0.5	0.10	0.04	0.02	0.01	0.00
1	0.20	0.08	0.03	0.01	0.00
2	0.36	0.16	0.06	0.02	0.00
5	0.67	0.35	0.15	0.05	0.01
10	0.89	0.57	0.27	0.10	0.02
20	0.99	0.82	0.47	0.19	0.04
50	1.00	0.99	0.79	0.41	0.10
100		1.00	0.96	0.65	0.18
200			1.00	0.87	0.33
500				0.99	0.64
1000				1.00	0.67

Table 2. Mean return period T and cumulative number N of earthquakes with magnitudes $M \geq M_i$.

M_i	T(Years)	N Calculated	N Observed
2.4	4.52	44	43
3.0	11.7	17	18
3.6	31.7	6	7
4.2	96.4	2	3
4.8	494	0.4	1

Table 3. Probability of occurrence of microearthquakes.

t (Years)	M_i 0.6	1.2	1.8
0.5	0.84	0.51	0.25
1	0.97	0.76	0.43
2	1.00	0.94	0.68
5		1.00	0.94
10			1.00

Table 4. Number of recorded seismic events.

Year	Total	Located	Detected	Source		
				Man-made	Tectonic	Unknown
1982+)	608	582	26	349	6	253
1983	1323	605	718	622	53	648
1984	2291	971	1320	999	191	1101
1985	1841	1162	679	1055	86	700

+) Local station operated only 3 months.

Table 5. Mean return period T and the cumulative number N_y per year of microearthquakes with magnitude $M \geqq M_i$.

M_i	T(Years)	N_y			
		Calculated	Observed		
			$M(\tau)$	M(Lg)	M(mean)
0	0.108	9.2	10.1		
0.6	0.274	3.6	8.6		10.1
1.2	0.695	1.4	1.5	10.1	8.3
1.8	1.77	0.56		8.6	1.2
2.4	4.52	0.22		1.2	

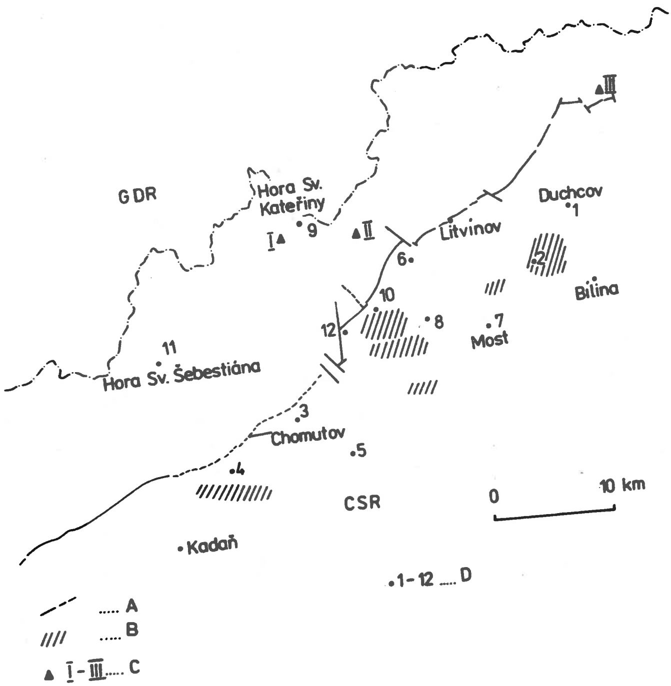

Fig. 1. Sketch of the study area. A - the Krušné hory Mts. fault, B - open-pit mines, C - foci of earthquakes determined on basis of isoseismal maps: I in the year 1877, II and III in 1896, D - earthquake foci in the years 1784 - 1, 1785 - 2,3, 1860 - 4, 1862 - 5, 1896 - 6 to 8, 1902 - 9, 1904 - 10, 1909 - 11, 1910 - 12 determined by single macroseismic observations.

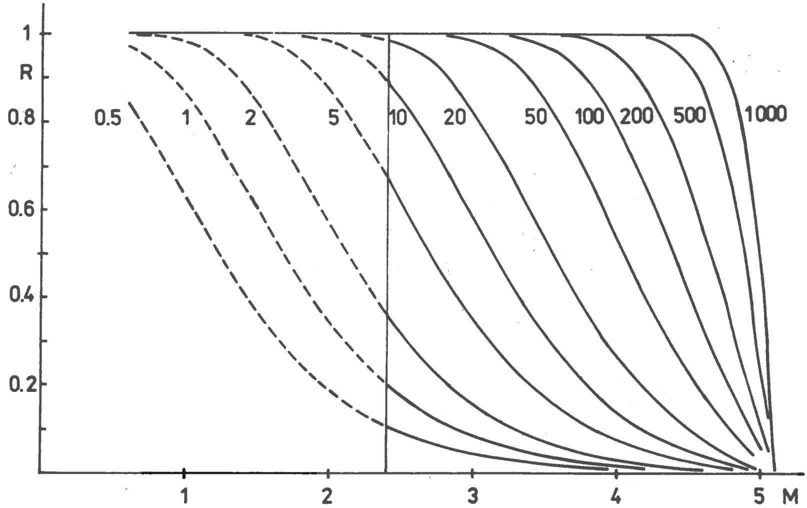

Fig. 2. Probabilities R of earthquake origin. Full curves for earthquakes with macroseismic effects, dashed curves for micro-earthquakes.

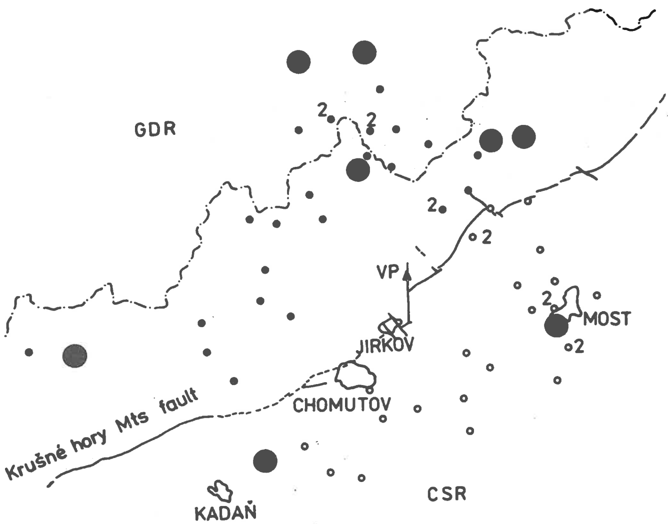

Fig. 3. Foci of tectonic shocks in the years 1982 - 1985. Large full circles - localization by at least three stations; small circles (full and empty ones) - localization by two stations. The number at epicentre gives the number of events with the coinciding focus. VP - position of local station Vysoká Pec.

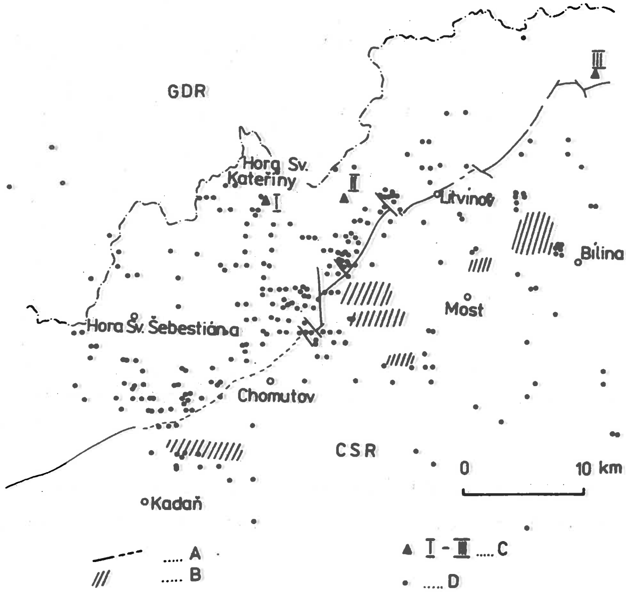

Fig. 4. Foci of shocks localized in the years 1982 - 1985, which originated in the day-time but were not classified as due to reported blasts. A, B, C - see Fig. 1.

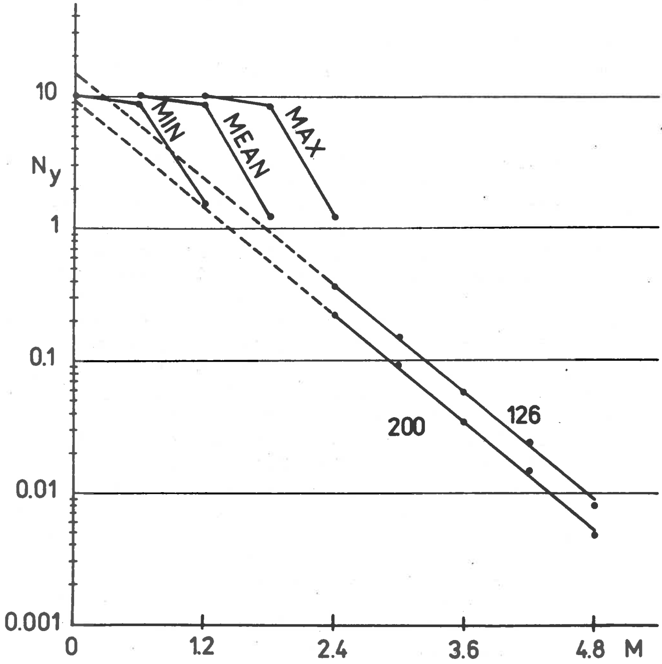

Fig. 5.

Fig. 5. Magnitude-frequency graph for annual cumulative frequencies N_y. Full line denotes the least-square approximation for observed earthquakes in the range of magnitude classes 2.4 - 4.8 and two observation periods 200 and 126 years. The extrapolated graph for microearthquakes is denoted by dashed lines. The cumulative frequencies for microearthquakes recorded in 1982 - 1985 are given for the magnitudes of station BRG: $M(\tau)$ - MIN, M(Lg) - MAX, and their mean value - MEAN.

EARTHQUAKE CATALOGUE AND SEISMIC MAPS OF THE GEOGRAPHICAL DOMAIN OF THE COMMISSION OF THE EUROPEAN COMMUNITIES

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1.- Introduction.

In the frame of the Commission of the European Communities, i.e. a geographical domain covering Belgium, Denmark, France, the Federal Republic of Germany, Greece, Ireland, Italy, the Grand-Duchy of Luxemburg, the Netherlands and the United Kingdom, Working Group Nr 1 has been established to consider methodologies, criteria, codes and standards in order to improve the safety of nuclear installations. Inside this working Group a special sub-group was devoted to the "Protection of Nuclear Power Plants against Seismic Effects". This Subgroup provided Working Group Nr. 1 with a comprehensive report on the reference seismic ground motions wherein, however, it appeared impossible to achieve a unique conception of seismic safety for all European countries for the following reasons:1) some Member-countries, up to now, did not experience any epicentre, while others know hundreds of them; therefore the procedures considered are not applicable in their entirety in areas of extremely low seismicity;2) seismic hazards are tied to regional seismotectonic systems which are disregarding national borderlines.Apart from that, consensus was achieved on two levels of reference ground motions whatever may be the approaches applied: the deterministic or the probabilistic one.Beside, the "Ahorner Report" shows some shortcomings:1) it should be completed by soil and structural aspects;2) the general safety philosophy needs a better confrontation of the seismic outcome with the earthquake resistant design topics;3) the lack of an harmonized seismic data bank.As regards these points, a second mandate was given to the Subgroup for completion of the above mentioned report as it was evidenced by the Review Group of Working Group Nr. 1.The elaboration of a general European catalogue and the preparation of seismic maps is now in full process. Nowadays, the geographical domain has been enlarged and includes also Portugal and Spain.

2.THE DATA BASE

Of its own nature and as it is to be collected in the different Member-countries of the European Community, the data base is all but homogeneous not only for what concerns its distribution in time and space, but also as regards the methods applied in the evaluation of the seismic parameters.Obviously, the data base comprises two main parts: the historical data and the present day data.

2.1. - The historical Data.

These data are confined up in an heterogeneous set of national catalogues. Albeit the only way to go back in time as far as possible in order to extend the period of investigation, none of them
refer neither to the same time-period nor to the same intensity-scale.Aside, written documentation may appear sufficient but not necessary reliable. The scarcity and the disparity of historical data constitute their greatest shortcomings. After all, they should be analyzed with the assistance of historians and lin-

guists for a better understanding of their content and significance.

2.2. - The present day Data.
The period under consideration for these data starts at the beginning of the 20th century as it was at that moment that the greater part of the European stations were installed.The present day data are to be split up in two groups:1) the instrumental data, and 2) the macroseismic data, provided by:a) the questionnaires, and b) the inquiries in situ.Both groups, of course, are complementary.Even, when since the beginning of the present century, reliable instrumental data are available,macroseismic data may have a great advantage over the instrumental ones as regards the historical seismicity or when estimating the future activity of a given region.The existing data base surely is stained by some shortcomings, but it can be improved as follows:1) in collecting macroseismic data more systematically by using a unique "intensity-scale" and an identical "questionnaire" in accordance with the adopted scale;2) data relevant to historical events should be gathered and then confronted among each other in order to eliminate misinterpretations, wrong evaluations, duplicates, a.s.o.;3) by compilation of comprehensive catalogues;4) by upgrading the instrumental quality of national seismographic networks..

3. - INTENSITY AND INTENSITY-SCALES.

Based on instrumental data only, the strength of an earthquake is expressed in terms of "Magnitude", while with macroseismic data the size of a shaking is given in "intensities".In order to evaluate the seismic risk at a given site, the number and the size of the earthquakes having struck the region must be known. The most appropriate procedure for estimating their strength, over a time-span as long as possible and on the base of historical and modern data, consists in applying a unique intensity-scale.Since the XVIIth century several scales have been devised. Mostly all of them are divided in three main parts:1) the lower range refers to the response of the population and to the type and degree of shaking of familiar objects;2) mid-scale are considered the various forms of damage to man-made structures;3) landsliding, faulting and other geological effects prevail in the upper part of the scales.Presently, the most used ones are:
1) the Modified Mercalli Intensity-scale; and
2) the MSK-64 scale.
Both scales have been re-evaluated. the first one by R.J. Brazee in 1978 and the second one has been revised by a special panel of the European Seismological Commission (ESC) in 1980.A comparison between the two new versions shows that the discrepancies between them are insignificant. Therefore the MSK-80 version is proposed for adoption in the countries of the European Communities.Unfortunately, all intensity-scales suffer serious extrinsic limitations stemming principally from:1) the methods of collecting the needed data;2) the lack of systematic approach to evaluation, i.e. more complete statistics should be used;3) the behaviour of new types of structures as multistory buildings;4) the missing of transfer functions connecting the degree of damage with the degree of intensity;5) the lack of relationships between intensity and soil condition, between intensity and ground motion parameters;6) the non-continuous calibration of the intensity-degrees with new corrected values of acceleration,

velocity and displacement;7) the non-inspection of struck areas y engineers in case of damaging earthquakes.

4.- THE MACROSEISMIC DATA.

4.1.- The Questionnaire.

Questionnaires are above all one of the best tools for harvesting macroseismic data when they are indited by seismologists active in the field of macroseismology. Unfortunately, they are different from one country to another and are, generally, not in conformity with the used intensity-scale. As regards this, the best fitting is found in Sponheuer´s questionnaire.After having compared the questionnaires used in Austria, Belgium, Denmark, France, Switzerland, the United States and that of Sponheuer, the following defects are found:1) the geographical situation is insufficiently described;2) the local soil conditions are not considered;3) the time of occurrence is inaccurate;4) nothing is mentioned about how the earthquake is felt: a single or a multiple shock;5) no attention is paid to the sounds emitted during the earthquake;6) the different types of constructions are not detailed.

4.2. - The Inquiries.

When earthquakes strike dwelled regions the effects on people, their immediate surroundings and their vicinity, are gathered and classified.An easy way to collect macroseismic data consists either in waiting for entering telephone calls from the stricken area or reading reports given by newspapers or noting the accounts emitted by other media.The best procedure to perform an inquiry consists in disseminating questionnaires and to make, simultaneously, a traverse survey. When the damages are of greater importance this survey should be made by both a seismologist and a civil engineer. The sooner this is done, the smaller will be the tendency for staining the truth by exaggeration. All, of course, depends on 1) the addressees of the questionnaire;2) the means used to distribute the questionnaires: by mail, the printed and the spoken press;3) the rapidity of replying;4) the responsibility of the collecting authority.However, the more abundant the gathered macroseismic material will be, the more precise the isoseismal charts will be mapped out.

5.- THE MICROSEISMIC OR INSTRUMENTAL DATA.

The greater part of the available seismic data is formed by macroseismic observations. But with the turning century these data were competed with instrumental ones read out from seismograms. Being obtained by simple measurements without any personal interpretation, they are said more objective and provide the following parameters:- the time of occurrence: hours, minutes and seconds; - the geographic coordinates; - the epicentral distance;- the hypocentral depth;- the magnitude: Mb, MS or ML;- the seismic moment;- the fault-plane solution.All these parameters, when considering the geotectonic aspects of the region, are very valuable quantities for selecting sites as they provide better knowledge on the geological features of the site-area.However, they should be complemented with strong motion data as regards the ground motion generated by earthquakes. From such records response spectra can be deduced which are more suitable for design purposes.

6. - THE CATALOGUE.

This subject is examined through the extant files. As fas as, either the elements to be put in the catalogue or the period to be covered are concerned, some disparities are to be overcome.The analysis of these files reveals:1) that the over all time-span considered should be subdivided in smaller periods;2) that each of these smaller periods should be assigned a lower limit of intensity.Taking these points into account, there are two main sections to be considered:1) the period going back in time as fas as possible and during which all parameters will have a macroseismic origin. Consequently, the yardstick for evaluating the size of earthquakes will be the epicentral intensity IO solely,2) the period running from 1901 up to now, called instrumental period.The first section, obviously, is to be divided in subsections according to some guiding principles as:- the Julian and the Gregorian Calender;- the evolution of the time-pieces (improvements in horology);- the times of the collapse of the Western Roman Empire;- the times before Christ.Concerning the lower intensity to be considered for the different periods, an acceptable consensus is rather a wager as the opinions are very diverging. Nevertheless, based on an argumentation described in the explanatory textbook, the following time divisions and the associated lower intensity-levels are proposed:

1) from BC up to the Vth century - Intensity Io=	VIII
2) from the Vth c. up to the XVIth "	VII
3) from the XVIth c. up to 1750 AD	VI
4) from 1751 up to 1900 AD"	V
5) from 1901 up to the present"	IV

As regards the fundamental earthquake parameters needed in a comprehensive catalogue, these are:

- the date: Year, month, day,
- the time: hours, minutes, seconds (up to 0,1 s)
- the geographical co-ordinates of the epicentre (to 0.01 deg);
- the magnitudes (MS, MB or ML);
- the maximum observed intensity Io;
- the focal depth (in km);
- the radius of perceptibility (in km);
- the name of the main place in the pleistoseist zone;
- the macroseismic map number;
- the bibliographic references;
- the main parameters of the fault-plane solution (XXth c. only);
- remarks.

7. - THE SEISMIC MAPS.

A catalogue should not be a simple repository in which the events are stored, but it rather should serve as a repertoire wherein pure scientists and civil engineers should find the necessary contribution to their performances respectively. An implementation of this consists in visualizing the parameters listed with the aid of maps.

7.1. - The Scale.

Drawing maps arises several problems. A first one resides in the scaling of the maps. At a scale of 1/10.000.000 and with computer-linked graphic systems, an epicentre can be plotted every 0,1 mm. This means that, at normal viewing distance, the points will be hardly separated given the resolving power of the human eye. Taking for granted that a distance of 0,5 mm is clearly distinguishable, the smallest scale acceptable for the European Community will be 1/2.000.000. But this may not refrain from making up general maps at smaller scales to have an overall view at a glance. Aside such charts, special maps for particular regions should be drawn at scales as large as 1/500.000 when necessary.

7.2 - The Projection System.

An other problem concerns the projection system of the maps. It is well known that each type of projection induces its proper alterations and distortions. Therefore, it seems advisable to agree on the same kind of map, the projection of which being a conic one with two standard parallels.

7.3. - The Tracing.

Next point on which consensus should be reached concerns the tracing of the maps. However, this is a minor one and will be solved easily by using different thicknesses of lining out the different types of lines (as parallels, meridians, coasts, isolines, country boundaries) and by applying different symbols for the different elements.

7.4. - Matters to be mapped out.

As all atlases, the envisaged one should provide information on a series of features to be expanded over either larger or smaller areas their importance respectively.
Three types of maps are to be considered:1) general maps covering the entirety of the territories of the Member-countries and the adjacent regions;2) regional maps spreading over several countries but constituting a seismic entity,3) national maps extending over one country and its neighbouring zones.In the present case, whereas seismic safety is implied, the following subjects are to be mapped out at a scale of 1/7.500.000:
- the tectonic features,
- the surface geology;
- the demographic distribution;
- the general epicentre map;
- the maximum observed intensity.

Aside these, national and regional maps should be made up at larger scales.These two kinds of maps should be made ready at the appropriate scales authorizing an easy read out and revealing delineations the significance of which may be of importance in siting problems.

8.- CONCLUSIONS.

8.1 - Several attempts were to be made to obtain the data from the different countries, moreover not one of the countries provided the data in the format asked for.
8.2 - More than 51.000 events have gathered for the 12 countries of the European Communities.
8.3 - Aside other inhomogeneities, the national catalogues were stained by "non native" earthquakes which were to be eliminated in order to avoid duplication of events. This operation is still in progress.
8.4 - Some national files did not produce a list of references; others did not mention the radius of perceptibility; none of the countries was in the position to procure focal mechanisms of their earthquakes.
8.5 - For what concerns the seismic maps, this problem will be settled as soon as possible when all the epicentral parameters will be available. All the maps will be drawn with the help of a mathematical procedure. This procedure is enough powerful to integrate over the whole area of Europe and the delineations for the different parameters foreseen will be performed with an adapted interpolation program.

A PROPOSAL FOR A NEW EARTHQUAKE-"QUESTIONNAIRE"

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Reviewing those applied in different countries as Belgium, Denmark, France, Switzerland, the United States of America, Austria and the "Sponheuer Questionnaire", it must be stated that the Questionnaires used are all but perfect and no one satisfies all the exigencies required by the safety aspects of modern life. Indeed, even in countries with low seismic activity, deeper knowledge concerning planning, housing and building should be expanded in order to reduce losses of lifes and goods.For achieving that aim, the vulnerability of the structures must be evaluated. Such an evaluation, in principal, is based on observations made in situ with a comprehensive questionnaire. But the questionnaires used up to now have many shortcomings:

1) The geographical situation is insufficiently described. Nothing is said about the topography. is the stricken place located in a plain, in a hilly or in a mountainous region;

2) in very few cases the questionnaires are dealing with the local soil conditions as the behavior of a building constructed on a soft soil is entirely different from that erected either on an unconsolidated material or on the solid rock;

3) the time of occurrence of an event is not always given with the necessary accuracy. Nowadays this can be overcome easily as watches are more and more precise and when the used time piece is of lower quality it always can be compared with time signals given by telephone, radio and television;

4) almost nothing is mentioned about how the event has been experienced: was it felt like a fast vibration, a slow undulation or as a unique or multiple shock; when observed indoors, did the vibration appear as to be confined to the room or was it felt as a shaking of the whole construction;

5) no information is asked about the direction of the abiration;

6) not enough attention is paid to the sounds emitted during an earthquake: - more care should be given on the moment the noises are heard: before, during or after the quake as this may be an indication concerning the epicentral distance; - the type of sounds could be described in a better way as claps, crepitation, rumbling, etc. are also distance indicators;

7) no one questionnaire relates anything about the types of constructions. They are making reference to the different kinds of damages only. A comprehensive questionnaire should contain at least a list of the different types of constructions with their shape, size and destination (housing, plants, official buildings, churches, etc.)

A questionnaire, wherein all these shortcomings have been incorporated, will enable to perform far more better macroseismic investigations leading to a more precise evaluation of the different degrees of damage to the man-made constructions and a better appreciation of the eventual metamorphosis of the natural environment.As far as all the information asked for should cover the most various domains and always must be of the greatest precision, it seems more appropriate to re-baptize the old-fashioned questionnaire and to name it "INQUIRY".

If some of the items of the inquiry seem to be out of date, it must be remembered that although the building processes evaluated from the reed and straw constructions up to the prestressed or the tensioned elements, rope thatch still employed in Scotland and Ireland. It must be said also, that aside these still alive building principles, not only consideration must be given to those designed during the last decades but also to the constructions belonging to the classical antiquity.
The best procedure to perform an inquiry consists in disseminating the forms and to make, simultaneously, a traverse survey. When the damages are of greater importance This survey should be made by both a seismologist and a civil engineer. The sooner this is done, the smaller will be the tendency for staining the truth by exaggeration. All, of course, depends on:

1) the addressees of the "Inquiry-forms". It goes without saying that the proposed "Inquiry-rom" can not be forwarded to anybody. In order to collect the most adequate replies, the addressees first must be empowered and secondly should enjoy the necessary knowledge to do so.
In order to benefit from both conditions, it is suggested to forward the "Inquiry" to the local administrative authorities as a mayor who can entrust the most appropriate people to collect the data. Another way for gathering the information consists in asking the "national police" to perform the inquiry. This however may be somewhat inconvenient the members of such a corps probably will be involved with the organization of the relief of the struck area.

2) the means to distribute them: by mail, by the printed and the spoken media;

3) the rapidity of replying;

4) the responsibility of the collecting authority.

So, when earthquakes strike dwelled regions the effects on people, their immediate surroundings and their vicinity are gathered and classified.The more abundant the gathered macroseismic material will be, the more precise the isoseismals charts will be mapped out.

INQUIRY (preliminary)

concerning the macroseismic effects observed during the

EARTHQUAKE of: year, month, day, hour, minute, second

I. LOCALIZATION

PLACE:	hamlet, commune, town, province
POPULATION:	number
GEOGR. COORDINATES:	lat, long, altitude in m above m.s.l.
TOPOGRAPHY:	The house is built on a plain/ hill/ mountain The village is located: on a plane/ in a depression/ on a crest/ on a slope/ along a river-bank/ a lake-bank/ seashore

II. GEOLOGICAL CONDITIONS

SOIL ASPECTS:	loose/ soft/ firm/ hard
SOIL CONSTITUTION:	alluvium/ sand/ loam/ clay/ filled up soil,rock
WATER CONTENT:	dry/ moist/ wet

III. TYPES OF HOUSING AND OTHER CONSTRUCTIONS

1) Occupation of the ground (in percent) by:
   - rural houses
   - urban houses
   - multi-story houses
   - high-rise blocks
   - public buildings: hospitals(no) storehouses(no) playhouses(no) schools(no) churches(no)
   - industrial buildings: plants(no) warehouses(no)
   - monuments (no)
   - historical buildings (BC) centuries (AD) centuries

2) Structural constitution of the housing

Type A	- Reed and thatch - Adobe, clay, field stone - Masonry: natural stone
Type B	- Masonry: hewn stone - bricks and tiles - Concrete
Type C	- Reinforced concrete - Prestressed concrete - Tensioned concrete - Framed and trussed buildings: Wood/ Iron/ Concrete/ Prestressed concrete/ Post-tensioned concrete - Prefabricated buildings

IV. THE OBSERVERS

- their number: a few persons/ many persons/ most persons/ the whole population
- their activity: walking/ sitting/ working/ standing/ resting/ laying back/ sleeping
- their behavior:

awaked:	no one/ a few/ many/ most
frightened:	no one/ a few/ many/ most
lost balance:	no one/ a few/ many/ most
ran outdoors:	no one/ a few/ many/ most
panicked:	no one/ a few/ many/ most

- their position:
  - a) away from the site (see: .....)
  - b) at the site:
    - 1) outdoors: sitting/standing/walking/ cycling/ driving/busy
    - 2) indoors at: the basement/ the ground floor/ a higher floor/ an upper floor

V.TIME OF OCCURRENCE

TYPE OF SHOCKS

a) Foreshock(s) at:	day, hour, minute
b) Main shock at:	day, hour, minute
c) Aftershock(s) at:	day, hour, minute
d) Number of foreshocks	
e) Number of aftershocks	

VI.ASPECTS OF THE EXPERIENCED EVENT

- A unique shock
- A multiple shock
- a fast vibration
- A slow undulation
- first movement: vertical/ upward/ downward/ horizontal
- direction to the: North/ South/ East/ West/ Northeast/ Northwest/ Southeast/ Southwest
- movement confined to: the room only/ the whole building
- The earthquake was felt: lightly/ distinctly/ awakening/ frightening/ strongly/very strongly

VII. NOISES EMITTED

The sounds were observed: before / during / after the earthquake

Types of sounds heard: Gusting/ Roaring/ Rumbling/ Knocking/ Creaking/ Ringing of house bells/of church bells/ Bumping/Rattling/ Crackling/ Exploding

VIII. EFFECTS ON THE IMMEDIATE PROXIMITY

- Vibration like those due to a light/heavy loaded truck passing by/ a heavy object falling inside the building (e.g.chandeliers, curtains, frames)
- Swaying of freely hanging objects at floor: very slightly/ slightly/ moderately/ violently
- Rocking of vases, standing pictures, knick-knacks, unstable objects
- Overturning, dropping and breaking of unstable objects
- Displacing of frames, light furniture
- Shaking of heavy objects and furniture
- Shifting of heavy objects and furniture
- Overturning of heavy objects and furniture
- Ringing of bells: small ones/ large ones
- Spilling over of full containers to: a small extent/ a large extent
- Domestic animals: became uneasy/ ran out of their stalls

IX. EFFECTS ON THE ENVIRONMENT

a) Changes in wells, springs, waters

- in wells waterlevel changed: occasionally/frequently
- springs changed their flow: occasionally/frequently
- springs stopped flowing: occasionally/frequently
- Dry springs restored flow: occasionally/frequently
- New springs turned up: occasionally/frequently
- Water turbid by mud or sand: occasionally/frequently
- Waves are formed on waters: small ones/ large ones
- Water is thrown on land: occasionally/frequently
- appearing of waterfalls: occasionally/frequently
- new pools or lakes: occasionally/frequently
- damming of lakes: occasionally/frequently
- deflection of rivers: occasionally/frequently

b) Changes of the ground surface

Cracks in ground (wet/dry):having a width
"b": 0<b<1cm: occasionally/frequently/numerous
1<b<10cm: occasionally/ frequently/numerous
10<b<100cm:occasionally/ frequently
b<1 m: exceptionally

Cracks in roads, slopes and riverbankshaving a width
b<10 cm: occasionally

Little landslides at roadways
steep embankments occasionally/frequently
hollows
steep slopes

Landslides over large ares: occasionally
Changes of shorelines by: subsidence/ elevation
Considerable displacement: horizontal/ vertical

X. EFFECTS ON STRUCTURES

1. Damages to buildings

1.1 GRADE I: Slight damages (Cracks in plaster, fall of small pieces of plaster)

To buildings of Type A (See III,2): very few/few/many/most/all

To buildings of Type B (See III,2): very few/few/many/most/all
To buildings of Type C (See III,2): very few/few/many/most/all

1.2 GRADE II: Moderate damage (Fine cracks in walls, fall of fairly large pieces of plaster, slipping off of pantiles, cracks in chimneys, parts of chimneys fell down)

To buildings of Type A (See III,2): very few/few/many/most/all
To buildings of Type B (See III,2): very few/few/many/most/all
To buildings of Type C (See III,2): very few/few/many/most/all

1.3. GRADE III: Heavy damages (Large and deep cracks in walls, Fall of chimneys)

To buildings of Type A (See III,2): very few/few/many/most/all
To buildings of Type B (See III,2): very few/few/many/most/all
To buildings of Type C (See III,2): very few/few/many/most/all

1.4.-GRADE IV: Destruction (Gaps in walls, continuous gaps in walls, loss of cohesion of building parts, collapse of inner walls, collapse of filled-in walls,parts of building collapse)

To buildings of Type A (See III,2): very few/few/many/most/all
To buildings of Type B (See III,2): very few/few/many/most/all
To buildings of Type C (See III,2): very few/few/many/most/all

1.5.-GRADE V: Total damage (Total collapse of buildings)

To buildings of Type A (See III,2): very few/few/many/most/all
To buildings of Type B (See III,2): very few/few/many/most/all
To buildings of Type C (See III,2): very few/few/many/most/all

2. Damages to other constructions

2.1.- To stone walls:

	fissures	in a few/ in many cases
	gaps	in a few/ in many cases
	overturned	in a few/ in many cases

2.2 To monuments and tombstones:

	moved	in a few/ in many cases
	twisted	in a few/ in many cases
	overturned	in a few/ in many cases

2.3 Railroads:

bending:	slightly	in a few/ in many cases
	heavily	in a few/ in many cases
	disruption	in a few/ in many cases

2.4 Roads: undulation of the surface:

	slightly	in a few/ in many cases
	heavily	in a few/ in many cases
degradation:	slightly	in a few/ in many cases
	heavily	in a few/ in many cases

Embankments, dams, dikes, bridges, piers, cranes, shipyards, canals and underground structures:

	slightly	in a few/in many cases
	heavily	in a few/ in many cases
Destruction:	partial	in a few/ in many cases
	total	in a few/ in many cases

3. Detriments to human life

Number of people injured: lightly
moderately
permanently

Number of victims: