Nationalkomitee für
Geodäsie und Geophysik
bei der Akademie der Wissenschaften
der Deutschen Demokratischen Republik

Akademie der Wissenschaften
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Zentralinstitut für Physik der Erde

XVIIIth General Assembly
of the
European Seismological Commission

Volume I

Leeds, August 23rd – 27th, 1982

Potsdam 1983

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Editor: H. Stiller
Co-editors: J. M. van Gils
P. Knoll

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I / 16 / 18 / 6.83 / 216 F 290 / 83

P r e f a c e

The 18th General Assembly of the European Seismological Commission was held in Leeds, United Kingdom, August 23 - 27, 1982. On request by the President and the Executive Council of the E.S.C., the Central Institute for Physics of the Earth of the Academy of Science of the German Democratic Republic has taken charge of the publication of the proceedings presented in this two volumes. In order to compromise with regard to actuality and completness of the scientific materials only those scientific and bussines papers have been included in these volumes which were available for the editors at May 1st, 1983. Therefore the scientific papers have been arranged in alphabetical order of the first authors names and do not follow the order of the activities of the subcommissions or symposia as held in Leeds.

Prof. Dr. H. Stiller
Editor
and
President of the E.S.C.

Contents

Volume II:

PRESIDENTIAL ADDRESS, August 23, 1982

A.R. Ritsema

Welcome at the 18th General Assembly of the ESC held jointly with the EGS. In 31 years of ESC no General Assembly has been held in the U.K., notwithstanding the rich history in eminent seismologists as well as developments in seismology from this country. The U.K. also has the longest tradition in international earthquake data centres, starting with the ISS in Kew, and now that of the ISC in Newbury. This combination of people and work was and will remain invaluable for the science of seismology. And I think, therefore, that it has been the right decision to accept the kind invitation of the U.K. to meet here in Leeds under the very able wings of the organizational committee, lead by Professor Jim Briden. We really are very grateful for this opportunity to meet here.

I welcome more specifically our colleagues from outside Europe, which have gathered here with us in greater numbers than ever before. We are very happy with this increasing interest in our organization from outside. We hope that this also will result in a closer factual co-operation between European seismologists and our non-European colleagues.

Our present meeting is the greatest ever held by ESC, with more than 170 papers to be presented. Also, it is probably one of the shortest in time being restricted to the greater part of one week only. This means that there will often be three or more parallel sessions for seismology only, which for us is a new experience. The Bureau was of the opinion, although not unanimously, that such a set-up should be tried out for once. Our experiences here will be of importance for the planning of future General Assemblies of ESC.

In the two years following our last Assembly in Budapest a great activity was shown by European seismologists, be it in the framework of ESC or not. A part of the work has already been described in the Activity Report 1980-82 of the ESC, being published this spring *). More complete reports will be presented later by the respective chairmen of Sub-Commissions.

As to seismic activities outside the ESC we may point to the now more or less regular discussions being held in Strasbourg at the Council of Europe. These meetings have resulted in a number of proposals for earthquake prediction research in Iberia, Italy, Greece, Turkey and Iceland in which also countries outside these regions intend to participate. In the sense of a careful formulation of research proposals of European countries this initiative of the Council of Europe has been a success. Much or all of the realisation of the proposals, however, will depend on as yet uncertain national funding.

Special attention also may be asked for the European Geotraverse (EGT), a 5 or 7 years effort starting in 1983 and being sponsored by the European Science Foundation to the amount of £ 1,8 million. It is a European contribution to the International Lithosphere Project. A 4000 km traverse from N. Scandinavia southward to North Africa, through the Precambrian and Caledonian shield area, the Hercynian C. Europe and the Alpine-Mediterranean sector is planned. The broad aim of the project is the better understanding of the formation of continental lithosphere and its behaviour under changing physical conditions in geologic time. The project is being introduced in Session SC6 by its principal reporters St. Mueller and E. Banda.

Another important point to be discussed in the present Meetings concerns the future of the European Mediterranean Seismological Centre, of which the financial status has been deplorable for the past several years. It is only thanks to the French govern-

*) L. Waniek, J.M. van Gils, A.R. Ritsema - ESC Activity Report 1980-1982, Publ. no. 160. Royal Netherlands Meteorological Institute, De Bilt (1982).

ment that its activity has not already been stopped altogether. An open meeting on EMSC matters has been planned and I hope that representatives of many countries will be present to express their interest in the continuing existence of EMSC and to actually support the future status of the centre.

I come now to the end of my address: The most destructive earthquakes in the European area since our last General Assembly were those of October 1980 in El Asnam, Algeria, magnitude 7.7, with ~ 3500 casualties; of November 1980 in Southern Italy, magnitude 6.9, with ~ 3000 casualties; and of February 1981 in Greece, magnitude $6\frac{3}{4}$, with many aftershocks and ~ 20 casualties. Apart from these great earthquakes major damage was also caused by earthquakes in Turkey, Albania, Yugoslavia and elsewhere. Again, as I said in my address of two years ago, none of these earthquakes have been forecasted by the seismological community in the way our meteorological colleagues predict the weather. Evidently, we have still to learn a lot more. We hope to proceed to this ultimate goal during these days in Leeds.

I wish all of you fruitful discussions and much inspiration for new work in the next two years.
Herewith I declare the 18th General Assembly of ESC opened.

BUSINESS PAPERS AND REPORTS OF SUBCOMMISSIONS

MEETING REPORT

SC2. P.M. on 23/8/82

The programme for the meeting opened with the presentation of contributed papers grouped within the framework of the Working Groups for Instrumentation, Data Collection and Standardisation. These proceeded as follows:-

a) Instruments. (Chairman: P.L. Willmore)
The two scheduled papers (abstracts already published) were presented.

b) Data Collection. (Chairman:H. Aichele)
No special papers were scheduled for this session, but the Chairman gave an introduction with a detailed review of the objectives of the Working Group.
A new era of seismological data processing started in the early sixties, when the first PDE cards were distributed with the aid of computers. The W.G. on Data Processing and Collection was especially concerned, from the time of its foundation in 1972, with the questions of data transmission of phase data, the intercorrelation between data centers and single observatories, the necessity of regional centers, the improvement of data handling and the reliability of the data. All this concerned phase data read from seismograms by an observer.
Now with the possibility of digital recording systems, new problems for data processing and exchange of this original data have come to the attention of the working group. Moreover, the items that have been discussed in the last years have to be reviewed from the standpoint of the new recording techniques and data processing and handling possibilities.
In this context, Dr. Lennartz as representative of an ad hoc working group presented an elaborated proposal for a standard format, especially designed for the data exchange. Concerning this proposal and the mentioned topics a lively discussion followed. As a result of this discussion it was recommended that the W.G. should continue to include the discussion of problems of processing and exchange of digital data into their topics. Further discussion should take place at the symposium of Digital Data

Acquisition and Processing in Seismology in GDR in 1983 as well as at the 1983 IASPEI-meeting and should be presented at the next ESC meeting.

c) Standardisation. (Chairman: N.V. Kondorskaya)

By way of introduction to the scientific papers, the Chairman underlined the need to continue the work in the following directions:

i) unification and standardisation of magitude determinations, notably in respect of the correspondence between regional and teleseismic data and the magnitude classification of deep focus earthquakes;

ii) determination of hypocentral parameters using European velocities;

iii) determination of earthquakes dynamic parameters from spectral characteristics using analogue and digital data.

The participants accepted the Chairman's proposal to compile a summary of the source parameters for several strong earthquakes in Europe, comparing the results of applying different methods of interpretation.

The session concluded with the presentation of the scheduled papers and three informal contributions.

The administrative session (Chairman: P.L. Willmore) proceeded as follows:-

1) Presentation of Chairman's report for 1980-82 (copy supplied).

2) Future activities of Working Groups.

a) Instruments. Developments in instruments and data processing up to March 1983 would be reviewed at the Symposium to be organised by the Academy of Sciences of the GDR in Castle Reinhardsbrunn from 14-19 March 1983.

b) Data Collection. Active discussion in the Europen context was continuing and would be reviewed in the framework of the IASPEI of the XVIII General Assembly of IUGG (Hamburg, 15-27 August 1983). The Central Recording Station of the FRG was organising a Summer School in digital data process (not a Working Group Meeting) in Erlangen in advance of the IUGG Assembly.

c) Standardisation. Membership of the W.G. was being reviewed, and work would continue with particular reference to collaboration with the ISC.

3) Election of Officers and other members

P.L. Willmore resigned as President and H. Aichele was elected in his place. J. Hjelme continued as Vice-President.

C.L. Teupser, H. Aichele and N.V. Kondorskaya remained as Chairmen of the W.Gs.

C.A. Gvishiani was invited to join the S.C.

P. L. Willmore

E. S. C.

SUB-COMMISSION ON DATA ACQUISITION
WORKING GROUP ON STANDARDIZATION

PROGRESS-REPORT: ACTIVITIES FOR 1981-1982;
SOME CONSIDERATIONS ABOUT FUTURE ACTIVITIES

According to the programm members of the Working Group worked in the following directions:

1. Unification and standardization of magnitude determination methods in seismological practice.

TELESEISMIC. In accordance with IASPEI resolution further attempts have been made to establish HMS for Eurasia. The system of station corrections and calibrating functions for P-waves were completed by those for S- and L-waves. The results are to be published by Academia Press in Czechoslovakia (Christoskov, Kondorskaya, Vanek) and the shortened version has been submitted for publication by the World Data Center-A (USA). The previous publication of WDC-A for P-waves has been translated into Chinese and printed in Peking in 1981. HMS has incorporated 8 stations (4 Indian, 4 Swedish ones). Some stations of south-western Europe are supposed to be included in HMS.

REGIONAL. Further development of earthquake classification in region was achieved. Several investigations are carried out in the USSR (Kondorskays, Solovyova et al. - Calibrating curves for the Caucasus = 0-5° on short period instruments and 1.5-24° on broad band instruments); in Bulgaria (Christoskov, Samardjieva- Magnitude estimation on P- and S-waves on duration formula); in Poland (Gibowicz - magnitude estimation for microevents). Some steps for implementation of "Intruction for measurements and reporting of amplitudes and periods" have been made in many european countries. The increasing of amplitude and period data reported to ISC can be observed. One of the most important future program is the correspondence between regional and teleseismic data and also the magnitude classification of deep focus earthquakes.

2. Determination of hypocenter parameters.

Some steps have been made in establishing separate blocks and their velocity structures in Europe. The estimation is based on DSS data, namely long profiles that cross all basic european structures now (Pavlenkova - USSR, Giese - FRG). It should be discussed whether the data obtained can be used in seismological practice.

While determining focal depth the special attention was paid to yielded waves reflected near by the epicenter. The use of polarized analysis for this purpose is studied in USSR (Kondorskaya, Medrov), and the use of synthetic seismograms - in FRG (Kind, Seidl).

3. Determination of earthquake dynamic parameters in seismological practice.

In this field the following methods were developed:

- study of spectral characteristics of seismic waves - in Czechoslovakia (Vanek, Pleshinger, Plomerova);
- seismic moment, energy, spectral magnitude determination - in FRG (Berckhemer, Duda, Nortman, Purcaru, Seidl);
- spectral magnitude determination - in Sweden (Shapira, Kulhanek);
- works on unified selection and calculation of P-wave spectra for determination of focal dynamic parameters - in USSR (Kogan, Moskvina, Zakharova, Chepkunas).

While preparing this meeting of the Working Group at Leeds, the members of the WG were proposed to compile a summary of the source parameter determination for several strong earthquakes in Europe (hypocenter location, magnitudes, energy, spectra, seismic moment, mechanism, seismic moments tensor, rupture extension, etc.). The main purpose of the work like this is to compare the results of different methods and to find the best approach to interpretation.

N. V. Kondorskaya
Chairman

List of earthquakes

	Date	To	M	Region
1	Jan 1, 1980,	16:42	6.9	Azores
2	May 4, 1980,	18:35	6.2	Caspian Sea
3	Oct 10, 1980,	12:25	7.5	Algeria
4	Nov 23, 1980,	18:34	7.0	South Italy
5	June 11, 1981,	07:24	6.8	Iran
6	July 28, 1981,	17:22	7.2	Iran
7	Dec 19, 1981,	14:10	6.9	Greece
8	Dec 27, 1981,	17:39	6.3	Greece

Subcommission of Physics of Earthquake Sources

Progress report:

Increasing interest in focal mechanism determinations and their use in seismotectonic studies demands a critical examination of existing fault plane solutions. For this reason it was found of interest to compile a catalogue of Mechanisms of European Earthquakes. A circular letter has been sent requesting information. Progress will be reported in next meeting of the SC.

A. Udias

Circular letter:

20 September, 1982

Dear colleague,

In the last meeting of the Subcommission on Physics of Earthquakes Sources, during the Assembly of the European Seismological Commission in Leeds (UK), it was decided to compile a catalogue of Mechanisms of European Earthquakes. This catalogue will include die following information:

<u>Region</u>

35°W - 60°E

30°N - 75°N (excluding Iran)

<u>Magnitudes</u>

M	6.5	1900 - 1950
M	6.0	1950 - 1980

- Some important events of magnitude 6 M 5 will also be included. These events will be given full coverage:
  - Nodal planes - with diagrams of P data and solution.
  - Other parameters independently determined.
  - Aftershock information.
  - Components of Moment Tensor.
  - References.
- All published solutions will be given with the appropiate reference.
- Solutions for smaller events 4 M 6 will be listed giving only the orientation of nodal planes and grouped in regions.

In order to compile the dates for this catalogue, I would appreciate that suggestions and all pertinent information (reprints of articles, P data diagrams, lists of data, references, etc.) is sent to me as soon as possible.

I hope that this catalogue can be compiled in a reasonable short time with everybody's effort and be of use to the European seismological community.

Sincerely yours,

Prof. A. Udias
President
SC Physics of Earthquakes Sources

Report of the meeting of the Subcommission on Microseisms and Seismic Noise, held 24 August 1982 in Leeds.

In an invited paper by Mykkeltveit and Bungum some seismic noise measurements in Norway and Finland were presented. They showed new results from a portable array concerning the power density and the correlation properties at 2-16 Hz.

Other papers included discussions of eleven-year variations of microseisms, new evidence for the microseismic barrier in the North Sea, discussions of seismic microregionalization and of multi-disciplinary investigations of microseisms. As a result of the general discussions, it was agreed that the 6-hourly readings of amplitude and period of microseisms are useful for locating microseismic storms in time and space.

C. Eva was elected as the new secretary of the Subcommission.

European Seismological Commission
Sub-Commission on Microseisms and Seismic Noise.

Activity report 1980 - 1982.

At the 17th general assembly of ESC in Budapest 1980 the following papers on microseisms were presented on 23 August 1980:

G. Cicconi, I.Dagnino, C. Eva: Comparative spectra of microseisms and swell in the Ligurian region (Italy).

V.N. Tabulevich: Application of observations included into the the project of microseismic storms.

V.N. Tabulevich: Stormy microseisms, geomagnetic storms and a complex of geophysical oscillations with frequency 0.1 - 1 hz.

R. Console, A. Rovelli: An analysis of ground and instrumental short period noise.

S. Tienari, H. Korhonen: Some problems in the measurement of storm microseisms.

E. Hjortenberg: Microseismic storm project.

On 21 of July 1981 a workshop on microseisms was held by the IASPEI Commission on microseisms at the 18th General Assembly of IUGG in London, Canada. The following papers were presented:

J. Darbyshire: Estimating the direction of approach of microseisms.

E. Hjortenberg: Extended material to the Microseismic Storm Project.

L.G. Holcomb: High-resolution spectral analysis of long-period microseisms.

H. Korhonen: Some advances and problems on observational microseism research.

As for the work on microseisms carried out in the other European countries reference is made to the papers listed above and to the bibliography of microseisms 1977 - 1982 given as an appendix to this report.

This bibliography aims to cover all references on microseisms during these years. Some of the members of the ESC Subcommission on microseisms have made important contributions to this bibliography. It illustrates a high continued interest in microseisms and seismic noise, in particular its applications for seismic zoning and investigations of sensitive seismic networks. It has been planned to publish the bibliography in the Fifth Report of the IASPEI Commission on microseisms.

Bibliography of microseisms, 1977-1982.

compiled by E. Hjortenberg,
Geodetic Institute, Gamlehave Alle 22,
DK-2920 Charlottenlund.

This bibliography covers 1977-1982 with a few later references added. Earlier references on microseisms and seismic noise may be found in the following bibliographies:

Gutenberg, B. 1956. Bibliography of microseisms, California Institute of Technology, CIT Technical Report, 2nd edition. (over 600 references).

Hjortenberg, E. 1967. Bibliography of microseisms 1955-1964. Geod. Inst. Skrifter, Ser. 3, v. 38, 112p, (566 references).

Hjortenberg, E. 1970. Bibliography of microseisms 1965-1967, reproduced by the Danish Geodetic Institute, Copenhagen, 25p, (247 references, some from 1968-1970).

For the time period 1968-1976 no bibliography on microseisms is available. References on microseisms and seismic noise may be found in the Bibliography of Seismology issued biannually by International Seismological Centre.

Only the first two bibliographies contained abstracts.

For the present bibliography the following references were used, among others:

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Annual Index of Current Earthquake Litterature. USGS Open-file Reports 79-396, 80-238, 81-454, 82-316. (i.e. up to 1981).
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Aleksandrov,A.L.Volodin,A.A.,Zelikman,E.I. and Nevskii,M.V. 1980. An instrumental investigation of periodic seismic signals, Seism. Pribory, v.13, pp 158-164, (pp 147-153 in the English edition, Seismic Instruments).

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CCD, Conference of the Committee on Disarmament, Feb. 1981. UK delegation. UK/GSE/10, Information on national seismograph station EKA. (p2: Estimates of noise levels).

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ESC: SC 5 Theory 5 Interpretation

Prof. H. Stiller, GDR Chairman

Prof. J. Behrens, Berlin-W Vice-Chairman

Dr. S. Franck, GDR Secretary

Progress Report

During XVII. ESC-General Assembly in Budapest 1980 SC 5 was established on the base of the following Working Groups (WG):

WG 1: Theory of wave propagation (Prof. Cerveny, CSSR)

WG 2: Experimental modelling of wave generation and propagation (Dr. Waniek, CSSR)

WG 3: High-pressure geophysics (Prof. Vollstädt, GDR)

WG 4: Complex interpretation of geophysical fields (Prof. Stegena, Hungary)

WG 5: Seismotectonic processes and fields

Unfortunately it was not possible up to now to find a suitable chairman for WG 5. But nevertheless there have been a lot of activities in this field an also this report will contain corresponding information.

1. Since the Budapest - meeting members of SC 5 particularly have been involved in the following conferences:

   - IASPEI-General Assembly, London (Ontario/Canada, 1981).
   - VIII. - International AIRAPT - High Pressure Conference, Uppsala/Sweden, 1981.
   - International Conference on Physical Properties of Rocks under Extreme p,t-Conditions and Application to Seismology, Taskent/USSR, 1981.
   - International Symposium on Physical and Geodynamical Processes in Earthquake Focal Regions, Potsdam/GDR, 1981.
   - International Conference on Physical Properties of Rocks and Minerals under High Pressure and Temperature, Zeleznij Brod/CSSR, 1982.
   - International Heatflow-Symposium, Liblice/CSSR, 1982.

Further activities are directed to:

- Symposium - "Theory and Interpretation", Leeds/GB, August 1982.
- Conference on Earthquake Prediction, Bucharest/Romania, April 1983.
- Workshop on Seismic Waves in Laterally Inhomogeneous Media, Liblice/CSSR, June 1983.
- Symposium on Time-dependent Processes and Properties in Planetary Materials, IUGG-General Assembly, Hamburg/FRG, August 1983.
- Preparation of a symposium of SC 5 "Theory and Interpretation" during the XIX. ESC-General Assembly, Baku/USSR, 1984, about methods and results of complex interpretation.

2. In Prof. Cervenys WG common work was concentrated on the following two topics:

   a) Construction of synthetic seismograms for inhomogeneous structures. For vertically inhomogeneous and radially symmetric media, several computing procedures, working with a high accuracy, are now available. For laterally inhomogeneous media with curved interfaces and block structures the situation is more complicated. For small models (with respect to the prevailing wave-length), the finite difference and finite element methods can be now effectively used. For large laterally inhomogeneous models (investigation of the structure of the Earth's crust and the upper mantle), usually some asymptotic methods are applied. Large emphasis is now devoted to the development of methods of synthetic seismogram computations for complex structures which would be as general as the ray method and which would work with the high accuracy as the wave methods. Large attention is also devoted to the seismic wave fields in the anisotropic media, dissipative media, random media, etc.

   b) Inversion of seismic data. This includes the inversion of the system of travel-time curves, and, perspectively the inversion of the whole seismograms. Large progress in this field can be observed in the inversion of seismic data for vertically inhomogeneous and radially symmetric media. For laterally inhomogeneous media, several new approaches are under investigation.

In the WG of Dr. Waniek main activities in the field of seismic wave modelling were done in relation to the focal process and to the thermal conditions in the relevant materials.
The activities of Prof. Vollstädts WG were as follows.
Laboratory high pressure investigations become more and more important for all the other problems that are investigated in SC 5. Progress could be reached in a stronger combination of laboratory data with real seismic and seismological problems. Further there have been special petrological experiments for the interpretation of structure and behaviour of the lithosphere. One example is the measurement of the thermal diffusivity of granitic rocks at high p,T as a basic quantity for thermal lithospheric models up to a depth of about 30...40 kms. First steps were done in investigating time and rate depending processes.
Prof. Stegena informed us that new results on elastic and thermal properties of the Earth's interior have been found in a cooperativ work between Soviet, Canadian, USA and Hungarian scientists. Based on the determination of exact velocity - depth functions for the crust and upper mantle of European platform areas, they performed calculations of the heat generation in the crust with the aid of velocity, heat flow and crustal thickness data. Furthermore a correlation between heat flow changes and sporadic weak crustal earthquakes in Europe was established. A good example for complex interpretation was also the common work of seismologists and theoretical physicists from Potsdam for relating anelasticity data of the Earth's core to the thermal state in this depth.
The main activity in the field of seismotectonics of the SC Theory and Interpretation was the Potsdam Symposium in November 1981, already listed above. This meeting was organized by the Central Earth Physics Institute of the Academy of Sciences of

the GDR and sponsored by KAPG and ESC. In our opinion the main step was the closer connection of certain relevant fields for seismotectonics. One example is the relation between stress and strain in the lithosphere and focal processes.
Besides the common activities on conferences and the publication of common scientific papers, the cooperation was also organized by the mutual exchange of preprints, papers, progress reports, and computer programs.

3. Further informations
(1) List of members of WG's:

WG 1: Červeny (ČSSR)
Gregersen (Danmark)
Helbig (Netherlands)
Jobert (France)
Kennett (England)
Mikhailenko (USSR)
Müller (FRG)
Neunhöfer (GDR)
Nolet (Netherlands)
Novotny (ČSSR)
Pec (ČSSR)

WG 2: Waniek (ČSSR)
Behrens (Berlin-W)
Dresen (FRG)
Shamina (USSR)
Strizkov (USSR)
Vinogradov (USSR)
Kozak (ČSSR)

WG 3: Vollstädt (GDR)
Babuska (ČSSR)
Proš (ČSSR)
Leliwa-Kopystynski (Poland)
Volarovich (USSR)
Bajuk (USSR)
Lebedev (USSR)
Seipold (GDR)
Wäsch (GDR)
Burkhardt (Berlin-W)
Lacam (France)
Hall (Scotland)
Volynets (USSR)

WG 4: Stegena(Hungary)
Horvath (Hungary)
Kropaček (ČSSR)

Lastovičkova (ČSSR)
Franck (GDR)
Kowalle (GDR)
Lubimova (USSR)
Teisseyre (Poland)
Wortel (Netherlands)
Jaoul (France)
Guterch (Poland)

WG 5: Work was done by geophysicists from different countries.

(2) Business

There have been no problems for business sessions in the WG, reports, and exchange of information.

Minute of the session of SC 5 "Theory and interpretation"

The session was held at 29.8.1982 a.m. There were presented 8 high-quality papers dealing with scientific problems of the Sub-commission and the activity report of the President of the SC. A discussion about further work and activity of the Sub-commission as well as the membership within the SC were included into the session.

The activity report and proposals about further activity were accepted by all participants of the session. Special dicisions were made to prepare a high-quality symposium during the 19. General Assembly of the ESC in Baku (1984) dealing with problems of modelling of the lithosphere by complex analysis of geophysical and other data.

Three papers dealed with seismic modelling in the lab. Kalkbrenner, Kim & Behrens and Kim & Behrens used modern digital filtering theory and wavelet analysis for analysing ultrasonic signals. Neumann & Behrens used tomographic techniques for the investigations of lateral velocity and attenuation anomalies in seismic modelling experiments. Radu, Winter, Rugina & Winter investigated rocks under periodic load.

They have shown a clear dependence of the acoustic emission and deformation on the stress-regime. Pantes, Delibasis & Lagios used explosions for the investigation of soil amplification and source parameters in a homogeneous geological medium. Abramovici has developed a new method for computing the SH-wave field generated in a stratified elastic medium. Kowalle, Stiller & Franck discussed the distribution of the seismic quality factor and viscosity in the Earth core and possible geophysical consequences.

Dragoni, Yven & Boschi investigated the exitation of Chandler wobble in a stratified viscoelastic Earth and discussed the role of different viscosity models of the asthenosphere for this effect.

EUROPEAN SEISMOLOGICAL COMMISSION

SUBCOMMISSION DEEP SEISMIC SOUNDING

ACTIVITY REPORT

1980 - 1982

L E E D S

AUG. 1982

Forward

Following the scheme adopted for the Strasbourg 1978 meeting, a joint activity report is presented for Northern, Southern, and Western Europe.

Information is based on questionnaires distributed Jan.8, 1982. Apart from some editorial modifications and additions, the replies received within June 30,1982 are presented unchanged in this report. The AA. our indicated and acknowledged. No attempt was made to present the individual reports in a uniform manner. This report is by no means complete, but at least the most relevant part of the research work carried through during the period covered by this report will have been mentioned.

Trieste, 10.6.1982

C. Morelli

Explanation of Paragraphs:

A1, B1, C1	Name of the project
2	Date of field experiments
3a	Experiment organized by (names and institutions)
3b	Other participants
4	Brief description of field experiments
5	Summary of the main results so far available
6	Possible continuations of this project
7	Publications
8	Position map with shotpoints and profiles
9	Examples of record sections if available
10	Figures showing main results is available
11	Do you plan other projects for 1983 and 1984?

AUSTRIA (Institut für Geophysik, Montanuniversität Leoben ; prof. E. Weber)

A1 Reflection seismic experiments using production blastings in the Erzberg - open cast ore-mine

2 Date of field experiment: July, October 1981

3 Experiment organized by Prof.Dr.F.WEBER and Dr.R.SCHMÖLLER
Institut für Geophysik, Montanuniversität Leoben

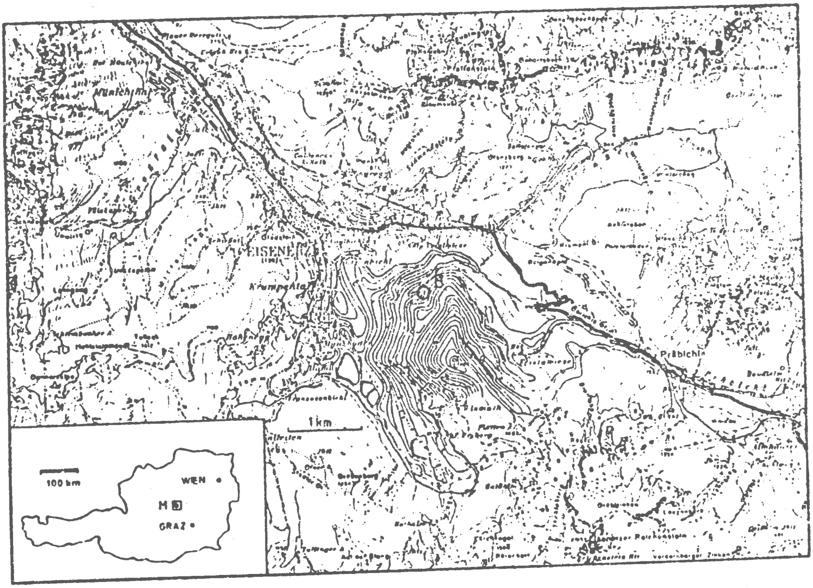
4 Field experiments
A 24-channel reflection seismic spread of 690 m length was used. The spread was layed out on a terrace of the open cast mine. There were blasts with explosive charges between 1100 and 4800 kg with delayed blasting stages.

5 Results
The reflection energy depends very much on the firmness of the rock in which the charge is blasted. Blasts of small explosive charges and only a few delay stages are more effective than big blasts with many delay stages. The first arrivals exhibit a near surface velocity of 4500 m/s. Good quality reflections were recorded with reflection times between 3 and 5 seconds. Assuming an average velocity of 5500 m/s this corresponds roughly to depths between 8 and 14 km. These reflection horizons are ascribed to some main boundaries of the alpine nappe system. There are some reflection events with traveltimes of ca. 13 seconds. Assuming again 5500 m/s this is roughly a depth of 36 km which corresponds quite fairly to the Moho in this position due to the results of the Lithospheric Seismic Alpine Londitudinal Profile 1975.

6 Continuation of the project
Occasionally supplementary measurements will be carried out in case of favourable shot conditions.

7 Publication
F.Weber, U.Duebon, R.Schmöller & G.Walach:
Jahresbericht 1981 über die geophysikalischen Messungen im Rahmen des Teilprojektes S 15/15. Die frühalpine Geschichte der Ostalpen (Hochschulschwerpunkt S15)
in press

8 Position map of the Erzberg-reflection seismic experiment



B = shotpoint   M = site of investigation

B.1 A deep seismic sounding experiment near Nikitsch, Burgenland, Austria

2 Date of field experiment: October 1981

3 Experiment organized by Prof.Dr.F.WEBER, Institut für Geophysik, Montanuniversität Leoben

4 Field experiments

For a deep seismic sounding experiment a favourable shot hole location was found 2.5 km NE Nikitsch, Burgenland, near the Austrian - Hungarian border. Two 24-channel reflection seismic systems were used simultaneously for recording. The experiment was performed to find out, if relatively small explosive charges, i.e. up to 55 kg, would be sufficient for gaining reflection seismic energy from the Moho. Two different layouts of geophone groups were used: a) a cross spread, i.e. two split spreads, 760 m long, vertical to each other b) an end-on spread, NE-SW, both seismic systems in line, total length 1460 m. The shot hole was drilled with a light drilling equipment of "Forschungszentrum Graz, Institut für Geothermie und Hydrologie." There were three blasts with different explosive charges: 6 kg, 18 kg and 54 kg, the lower end of the charges being at 12, 38 and 42 m.

5 Results

Besides good reflections from a tertiary horizon at 0.3 seconds and from the basement or some adjacent discontinuity at 0.48 seconds some fair quality reflections were recorded between 6.1 and 6.5 seconds. Assuming an average tertiary velocity of 1900 m/s and a crustal velocity of 5500 m/s these reflections come from a depth of approximately 18 km. This is the depth of the velocity inversion zone on top of the Moho, found 45 km south of Nikitsch on the

Lithospheric Seismic Alpine Londitudinal Profile 1975 There is also an outstanding fair reflection at 8.4-9.5 seconds, coming from a depth of about 24 km, in agreement with the depth of the Moho found on the Alpine Longitudinal Profile 1975 in the same W-E position.

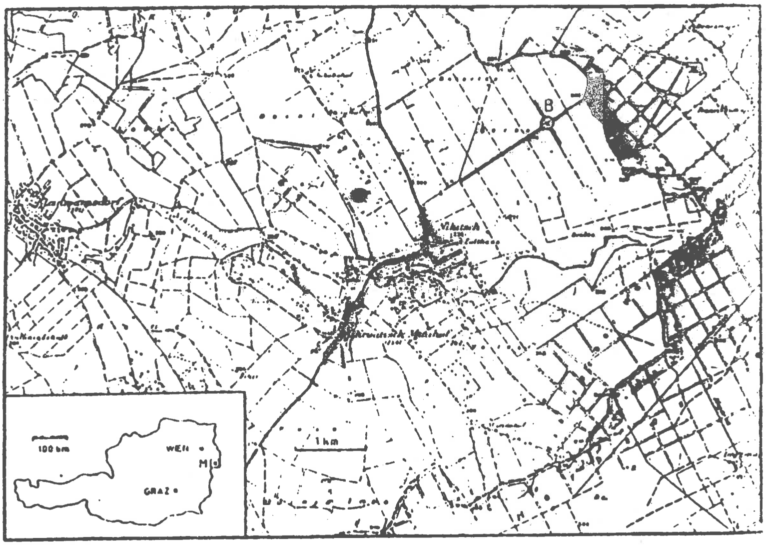
6 Continuation of the project

The investigation proofed that deep seismic sounding could be performed successfully as a routine procedure with relatively small explosive charges. Some further test experiments will follow.

7 Publication

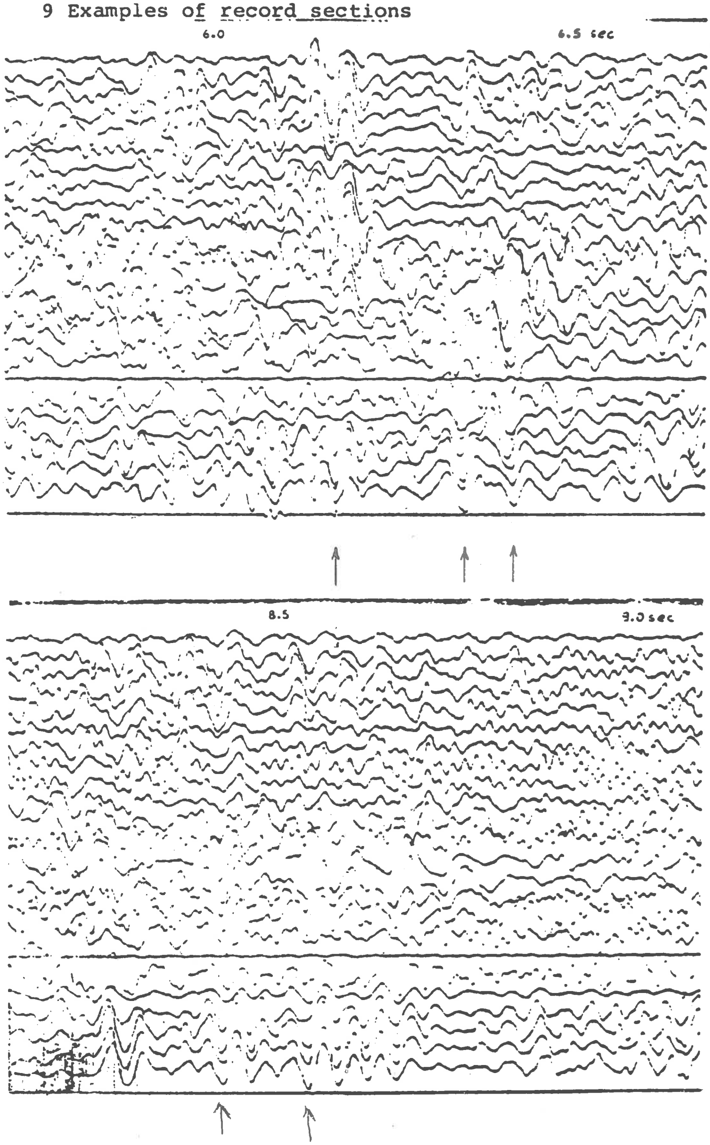
F.Weber, U.Duebon, R.Schmöller & G.Walach: Jahresbericht 1981 über die geophysikalischen Messungen im Rahmen des Teilprojektes S 15/15. Die frühalpine Geschichte der Ostalpen (Hochschulschwerpunkt S15) in press

8 Position map of deep seismic sounding experiment



B = shotpoint   M = site of investigation

9 Examples of record sections



FINLAND (Inst. of Seismology, Univ. of Helsinki; H. Korhonen, U. Luosto, E. Lanne)

The following DSS profiles in Finland have been advanced during 1980-82: FENNOLORA/FINLAP, SVEKA, Bothnian profile and Baltic profile. The locations of these profiles are indicated on the enclosed map, Fig 1.

A 1 FENNOLORA/FINLAP

2 The description about field work in the year 1979 is included in the E.S.C. activity report 1978-1980. The interpretion is in progress. The crustal thickness is about 50 km and average velocity in the crust 6.6 km. The following papers are presented: Luosto, U, Zverev, S.M., Kosminskaya, I.P. and Korhonen, H., Observations of Fennolora shots on additional lines in Finnish Lappland, EGS Meeting, in Budabest 1980. Luosto, U., Finlap-projekti: (abstract in English) X Geofysiikan päivät 23.-24.4.1981, Helsinki. Luosto, U., Fennolora/Finlap project (abstract) EGS Meeting, Uppsala, 1981

B 1 SVEKA

2 2.-12. June 1981

3a H. Korhonen and U. Luosto, Institute of Seismology, University of Helsinki, Finland

3b - Institute of Geophysics, Polish Academy of Sciences, Warsaw, Poland
- Department of Physics of the Solid Earth, University of Uppsala, Sweden

- Geological Survey of Finland, Finland
- Department of Geophysics, University of Oulu, Finland

4 - Geological location: across the Svecofennidic (1.8-1.9. Ga), Karelidic (2.0-2.3 Ga) and Archean (> 2.5 Ga) units
- length 320 km
- spotpoints: 5 points at the interval of ca. 80 km in small lakes (depth 4-10 m), charges 100-1000 kg TNT
- time signal and communication by the Finnish Broadcasting Company via public FM-channels
- 9 positions x 18 stations = 162 registration sites with the average station interval of 2 km
- equipments:

  10 SN-PCM-80 digital, 3-channels, from Helsinki
  6 Mars, FM, 3-channels, from Uppsala
  4 Polish, FM, 5-channels, from Warsaw
  1 Mars on crossing profile from Oulu

- vertical geophones, 200 m apart from each other and two 3-component geophones

5,6,7 The preparation of the data and interpretation is in progress. The interpretation will be performed at the Institutions participating in the field operation. First results will be reported in Leeds at E.S.C. 18 th meeting. According to preliminary interpretation the crust seems to be divided to several blocks separated by deep fractures. The thickness of the crust in the middle of the profile is about 55-57 km.

C 1 BOTHNIAN PROFILE

2 Quarry blasts since 1980

3a J. Yliniemi, Department of Geophysics, University of Oulu, Finland

3b Institute of Seismology, University of Helsinki, Finland

4 - the profile is performed by using the shots at Lahnaslampi (near Kajaani) and Kemi mines
- length about 300 km
- 3-component registrations with the average station interval of 5 km
- geologically the profile lies on the Archean basement complex except the younger Kiiminki shist formation on the NW part of the profile.

5,6 The data collection and preparation is in progress, some preliminary interpretations have started.

7 Yliniemi, J. and Luosto, U. Kaivosräjäytysten käyttö syväseismisessä luotauksessa. (abstract in English). X Geofysiikan päivät 23.-24.4.1981, Helsinki.

8 - See Fig 1.

11 Data collection will be continued for more detailed profiling.

D 1 BALTIC PROFILE (plan)

2 August 1982

3a H. Korhonen and U. Luosto, Institute of Seismology, University of Helsinki

3b USSR Academy of Sciences, Moscow,
Geophysical Departments of Universities: Uppsala, Kiel, Berlin (West), Oulu
Geological Survey of Finland

4 - the profile is parallel with DSS-profile SVEKA and runs over similar main geological units except in SW part where the profile crosses the Rapakivi massif.
- length: about 400 km
- shotpoints: 5 points in small lakes, 2 points on the sea
- communications as in SVEKA
- 40 stations on 5 positions makes 200 registration sites, additional stations (about 20) on a crossing profile (length 100 km)
- both multi-channel stations with vertical geophones and 3-component stations.

8 See Fig 1.

11 TRANSFEN profile, which connects SVEKA and Baltic profiles to Blue Road profile.

The authors would like to express their gratitude to the following Institutions for their substantial financial support to DSS programs:
Suomen Luonnonvarain Tutkimussäätiö (The Foundation for Research of Natural-Resources in Finland) Academy of Finland, Ministry of Trade and Industry of Finland.

Finl. 5

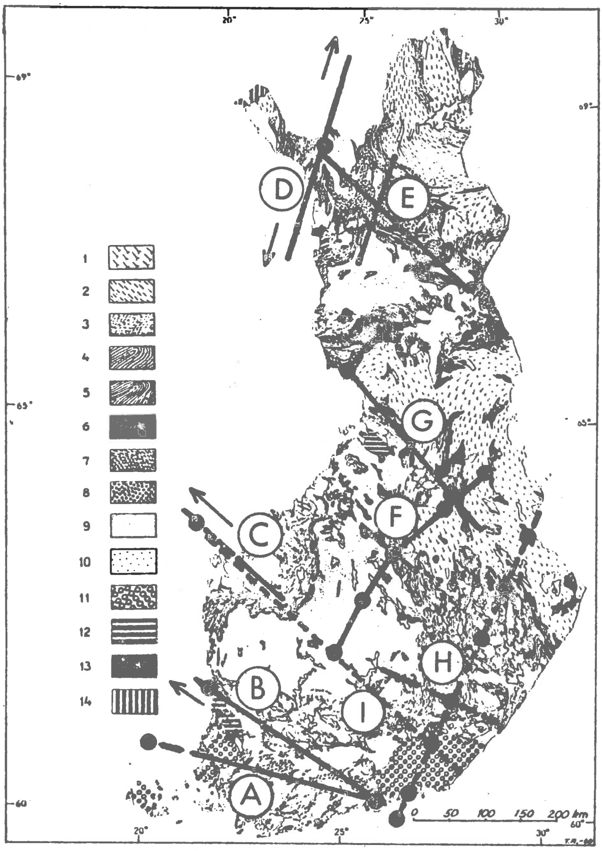


Fig. 2. Lithological map of the Precambrian in Finland. 1, orthogneiss; 2, granulite; 3, quartz-feldspar schist; 4, mica gneiss and migmatite; 5, phyllite and mica schist; 6, quartzite; 7, metabasalt and amphibolite; 8, gabbro, anorthosite and ultramafic rocks; 9, granodiorite and quartz diorite; 10, granite; 11, rapakivi granite; 12, nonmetamorphic sedimentary rocks; 13, diabase; 14, Caledonidic schists. Drawn by Toini Mikkola after the map compiled by A. Simonen.

Finnish DSS profiles. Solid line: field work carried out; dashed line: planned profile; dot: shot point.
A. Sylen-Porvoo (1965); B. Trans-Scandinavian (1969); C. Blue road (1972); D. Fennolora (1979); E. Finlap (1979), F. Sveka (1981); G. Bothnian (1980-); H. Baltic profile (1982); I. Transfen. (The year for the field work in parentheses.)

Fig. 1

GERMANY F.R.

Geophysikalisches Institut, Universität Kerlsruhe

A.1 Structure of the Crust and upper Mantle beneath the Central European Rift System.

. 2 1976 - 1978.

. 3 Geophysical Institute, University of Karlsruhe, Karlsruhe (F.R. Germany).

. 4 The crustal and upper mantle structure has been investigated predominantly with seismic methods piece by piece with varying techniques and results have been published by various authors.

. 5 Beneath the Rhinegraben the Moho is elevated, with a minimum depth of 25 km. Below the flanks it is a first-order discontinuity, while within the graben it is replaced by a transition zone with the strongest velocity gradient at 20-22 km depth. An anomalously high velocity of up to 8.8 km/s seems to exist within the underlying upper mantle at 40 - 50 km depth. A similar structure is also found beneath the Limagnegraben and the young volcanic zones within the Massif Central of France, but the velocity within the upper mantle at 40 - 50 km depth seems to be slightly lower. Here, the total crustal thickness reaches only 25 km. The crystalline crust becomes extremely thin beneath the southern Rhônegraben, where the sediments reach a thickness of about 10 km while the Moho is found at 24 km depth. The pronunced crustal thinninh does not continue along the entire graben system. North of Rhinegraben in particular the typical graben structure is interrupted by the Rhenohercynian zone with a "normal" West-European crust of 30 km thickness evident beneath the north-trending Hessische Senke. A singleended profile again indicates a graben-like crustal structure west of the Leinegraben north of the Rhenohercynian zone. No details are available for the North German Plain where the central European rift system disappears beneath a sedimentary sequence of more than 10 km thickness.

. 6 -

. 7 Prodehl C., 1981 : "Structure of the Crust and upper Mantle beneath the Central European Rift System". Tectonophysics, 80, 255-269.

. 8 Fig. 1

. 9 Fig. 2

.10 Fig. 4,9

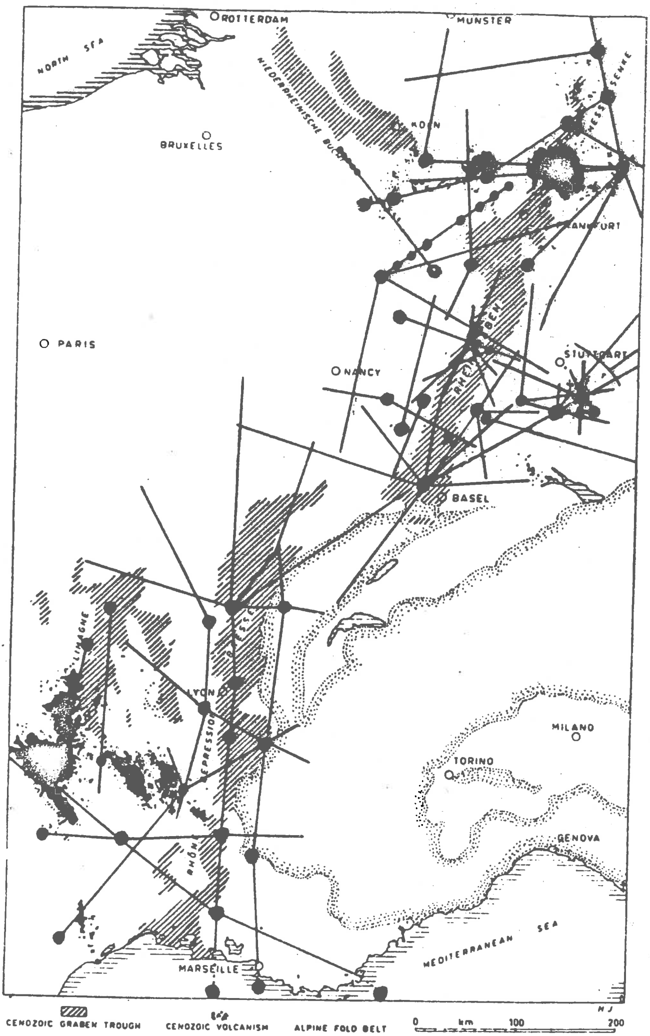


Fig. 1. Location map of explosion seismology surveys ot the central European rift system. Base map showing Cenozoic graben troughs and Cenozoic volcanism from Illies (1973).

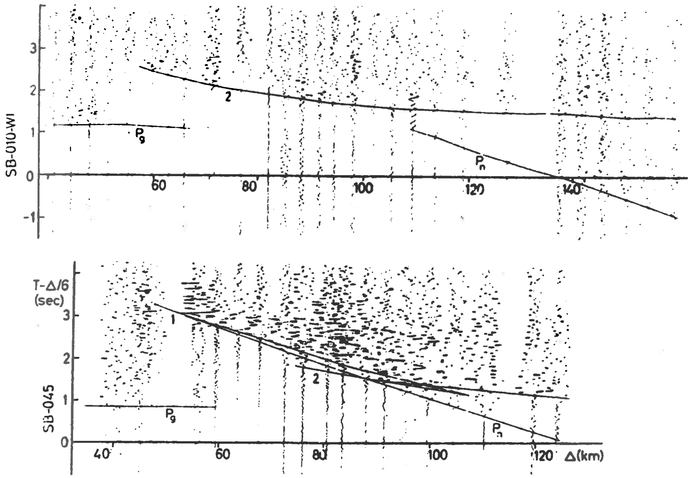


Fig. 2. Part of record sections of seismic-refraction profiles in the Rhinegraben (SB-010-WI) and the adjacent Black Forest (SB-045). From Prodehl et al. (1975, fig. 3).

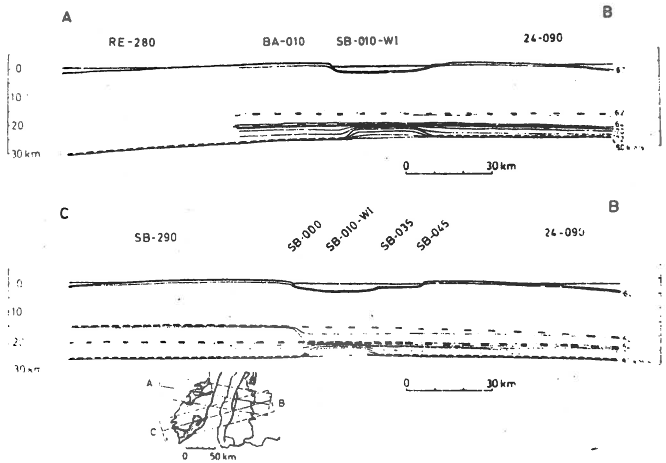


Fig. 4. Crustal sections through the southern part of the Rhinegraben. Thin lines = lines of equal velocity, contour interval 0.2 km/s; thick continuous line = surface of the crystalline basement; thick dashed lines = mean depth of the main crustal boundaries. From Edel et al. (1975, fig. 16).

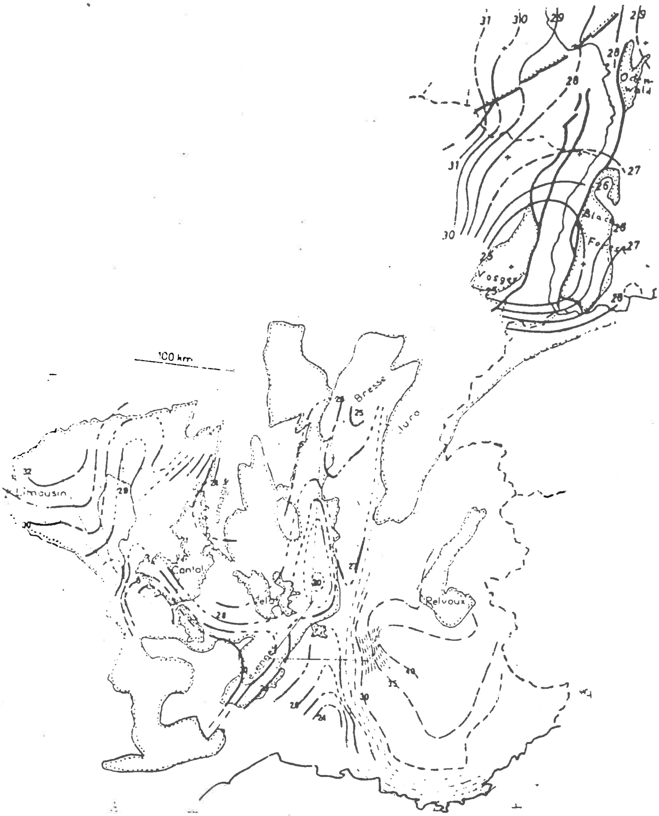


Fig. 9. Contour map of the depth to the crust—mantle boundary along the central European rift system through southeastern France and southwestern Germany. Compiled from Hirn (1976) and Edel et al. (1975).

1 CRUSTAL STRUCTURE OF THE RHENISH MASSIF BASED ON THE 1978 - 79 SEISMIC REFRACTION EXPERIMENTS

J. Mechie, C. Prodehl, and K. Fuchs - Geophysikalisches Institut, Universität Karlsruhe, 75 - Karlsruhe 21., Hertzstr. 16.

During 1978-9, a seismic refraction experiment to investigate the crust and upper mantle structure beneath the Rhenish Massif was completed. The 6ookm long main profile extended from the Paris basin in the SW, across the Devonian slates, quartzites, and limestones of the massif itself, to the Hessische Senke in the NE. The cross profiles, up to 17okm long, were almost wholly located in the massif. From this experiment, over 3ooo three-component recordings were obtained and from these, 27 record sections from 14 shot-points with maximum recording distances ranging from 5o-6ookm were constructed.

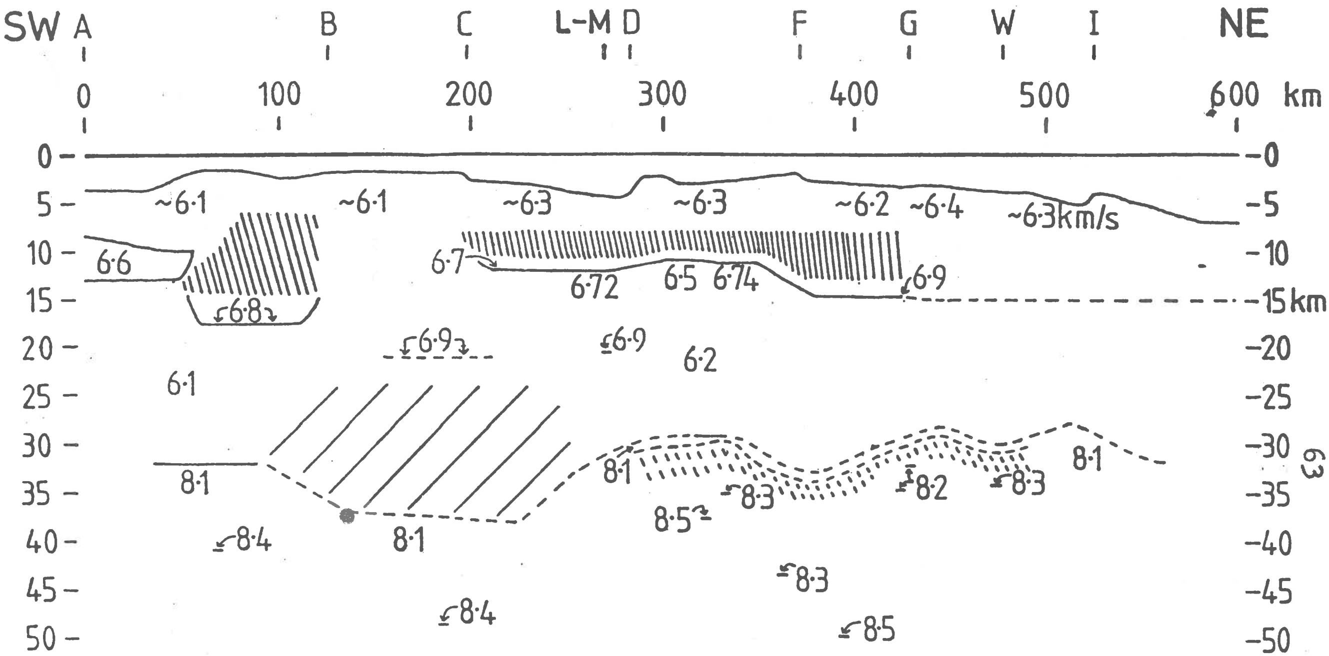
The P_g phase is observed on every record section, sometimes out to a distance of 15okm. It is the refracted phase, with velocity ranging from 6.1-6.4km/s, from the upper crust below an average depth of 3-5km. On almost all record sections, additional intracrustal phases can be recognized. The boundaries or, in many cases, the strong transition zones producing these phases are of variable lateral extent and occur in the depth range 9-24km.

The crust-mantle boundary structure beneath the profiles also displays marked lateral variability. In the SW, under the Paris basin, it is a sharp boundary at ~32km depth. Eastwards along the profile, beneath the southern Ardennes, including Luxembourg, an upper mantle velocity of 8.1km/s is not reached until ~37km depth, and there is a strong indication of a transition zone between 29 and 37km depth.

Beneath the Eifel, especially the East Eifel, Quaternary volcanic fields, there is a thin ($\leq$1km thick) high velocity layer (V=8.1km/s) beneath a sharp boundary between crust and mantle at ~29km depth. Below the thin high velocity layer, there is a 6km thick transition zone, in which the velocity increases from low values (~6.4km/s) to upper mantle values (~8.4km/s). At greater depths (~5o-15okm) beneath this area, there exists the low velocity anomaly detected by analysis of teleseismic P-wave residuals (S. A. Raikes, pers. comm.).

Northeastwards along the main profile, under the eastern end of the Rhenish Massif and under the Hessische Senke, the crust-mantle boundary which is still sharp falls to ~31km depth, before it again rises to ~29km depth. It is possible that under some of this area there also exists at the top of the mantle the thin high velocity layer overlying the transition zone, as described above for the Eifel area.

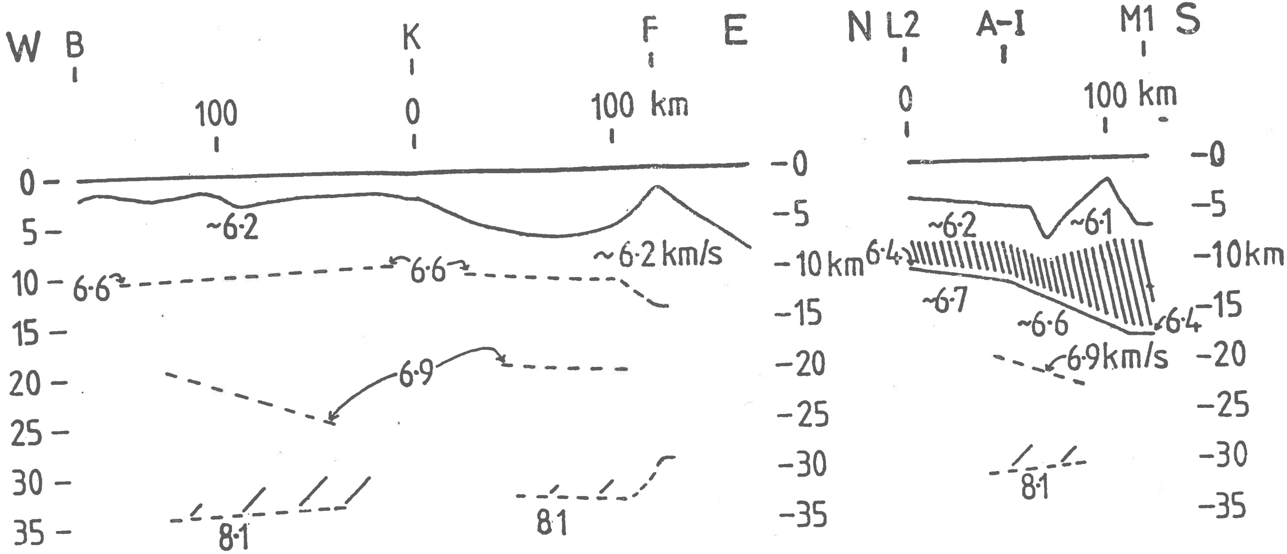
Along the cross profiles, mainly towards the northwest of the main profile, it appears that the crust-mantle boundary structure is a 2-4km thick transition zone, with an upper mantle velocity of 8.1km/s being reached at 3o-33km depth.



Cross-section, showing 2-D velocity structure, along the main profile.

Key: —— model determined by ray-tracing; - - - model determined by 1D V-Z functions; |||||| upper crustal low-velocity layer (only shown where model determined by ray-tracing); / / / transition zone between crust and mantle; ¦¦¦¦¦¦ transition zone in upper mantle.

Germ.FR.7



Cross-sections, showing 2-D velocity structure, along the cross profiles.

Key: see other figure.

Institut für Geophysik, Kiel (dr. E.R. Flüh). Germ.FR.9

C.1 Geotraverse Rhenoherzynikum III - Reflection Profil near Aachen

2 09.08.78

3 a Institut für Geophysik, Kiel

3 b Prakla Seismos GmbH, Hannover

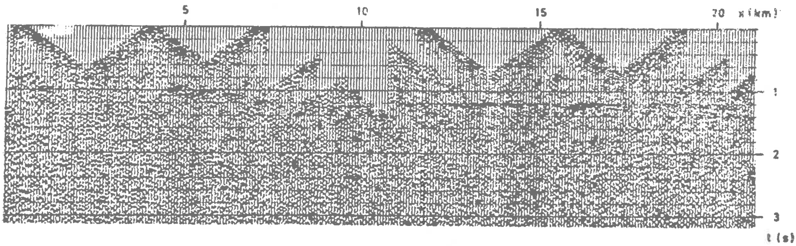
4 3 48 Channel Reflection equipments, 10 Mars Stations. 15 Shot-points, 37 km Profil

5 Shallow reflector (3-4 km) indicating thrust fault at northern end of Rhenish Massif in the "Hohes Venn" - area, Mohodepth 30 km

6 Summer 1983

7 Meissner, R., Bartelsen, H. and Murawski, H., 1981: Thin-skinned tectonics in the northern Rhenish Massif, Germany; Nature 290, 399-401

10 Section showing shallow reflector



Institut für Geophysik der Freien Universität Berlin (prof. P. Giese).

D.1 Andean Geotraverses

.2 Jan.-March 82

.3a Geophysical Institutes
Freie Universitat Berlin
and Universidad del Chile, Santiago

.4 Seismic and magnetotelluric measurements along a profile in Northern Chile and Southern Bolivia. Explosion in the copper mine Chuquicamata are used as seismic energy source. A first 220 km profile was observed between the mine and Antofagasta, a second line, running eastwards and traversing the Western Cordillera and the Altiplano has been started.

.5 Not yet

.6 Aug - November 1982

.7 No

.8 -

.9 -

.10 -

.11 EGT 1983
Oberpfalz 1982/83
joint program with Munich.

ITALY (Italian Explosion Seismology Group).

A. 1 Southern and Eastern Alps.

2 1977-78.

3a Istituto di Miniere e Geofisica applicata, Università, Trieste (C. Morelli).
Osservatorio Geofisico Sperimentale, Trieste (R. Nicolich).
Institute of Geophysics, E.T.H., Zürich (S. Müller).

3b Istituto di Fisica, Università di Lecce (M.T. Carrozzo, D. Luzio).
Istituto Geodetico e Geofisico, Università di Genova (C. Eva, M. Merlani).
Istituto di Geodesia e Geofisica, Università di Bari (G. Calcagnile).
Istituto di Geodesia e Geofisica, Università di Trieste (G. Panza).
Istituto per la Geofisica della Litosfera, CNR, Milano (V. Carli, R. Cassinis, B. Colombi, S. Scarascia).
Istituto di Scienze della Terra, Università di Catania (M. Cosentino).
Istituto di Scienze della Terra, Università di Udine (M. Riuscetti).
Osservatorio Vesuviano, Ercolano, Napoli (I. Guerra, G. Luongo, R. Scarpa).

4 During Summer 1977, within the frame of the Geodynamics Project, a seismic profile was carried out in the Southern Alps. It was intended as the necessary complement to the Alpine long-range profile executed in 1975 in the Central Alps.

The data collected in this experiment are presented together with those of a 1978 profile in the Eastern Alps.

5 The main results concerning the crustal structure are:

- The Moho discontinuity of the European plate, at a depth of about 30-35 km in the molasse basin, reaches the maximum depth of 55 km along the axis of the Alps. Southwards, up to the Varese-Udine line, the discontinuity is detected at depths of 25 to 45 km.

- A shallower discontinuity, with P-wave velocity of 7.0 - 7.5 km/s, has been detected at a depth of 20-30 km in a wide region covering approximately all the Eastern Alps.

- At the margin of the Po Plain (Adriatic plate) and in the Pannonian basin the depth of the Crust/Mantle boundary is about 30-35 km.

Questions concerning the interaction between the African and European plates suggest the possibility of remarkable overthrusting movements at crustal levels in the Alpine region. The available results on surface wave dispersion have been analyzed and an attempt has been made to estimate the average S-wave velocity in the crustal low-velocity layers, outlined by DSS data interpretation. The S-wave velocity distribution in the Upper Mantle has been determined in areas close to the lid and an underlying low-velocity layer have been detected. A thinning of the lid in the easternmo-stportion of the considered area seems to indicate the extension of the tensional field of the Pannonian basin under the Alpine system.

. 6 -

. 7 Italian Explosion Seismology Group, Institute of Geophysics, ETH Zürich : Crust and Upper Mantle structures in the Southern Alps from Deep Seismic Sounding Profiles and surface wave dispersion analysis". Boll. Geof. teor. appl. Trieste, XIII, 92.

. 8 Fig. 1.

. 9 Figg. 2 - 3.

.10 Figg. 8-13, 15-16, 22-27.

.11 -

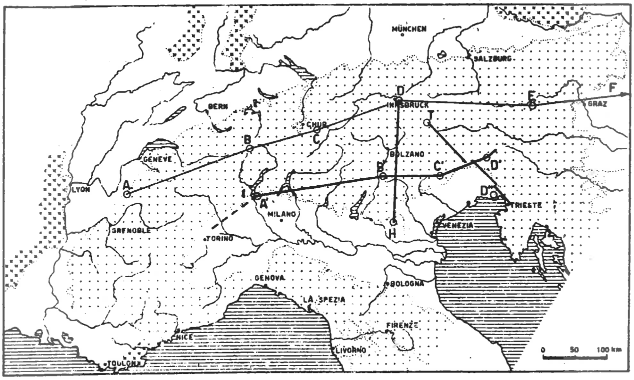


Fig. 1 — Position map of profiles and shot points. Thin lines, observed in 1975; thick lines, in 1977 (profile A'-B'-C'-D') and in 1978 (profile D"-T). Dotted area, Alpine orogenic system; blank, postorogenic basins; crosses, external massives.

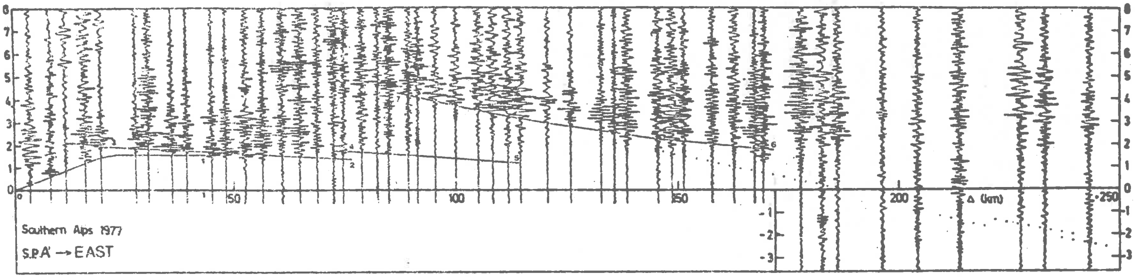


Fig. 2 — Record-section from S.P. A' to S.P. B'. Lines correlating the main phases are numbered.

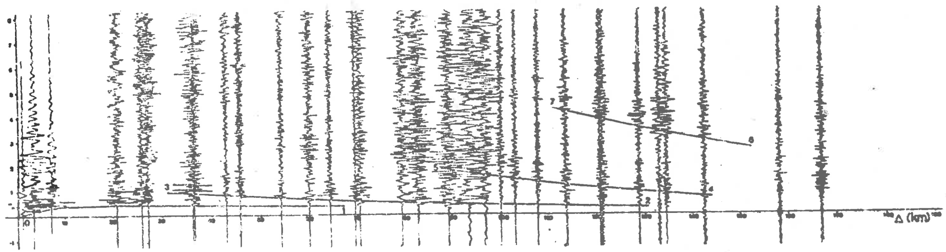


Fig. 3 — Record-section from S.P. B' to S.P. A'. See caption of Fig. 2.

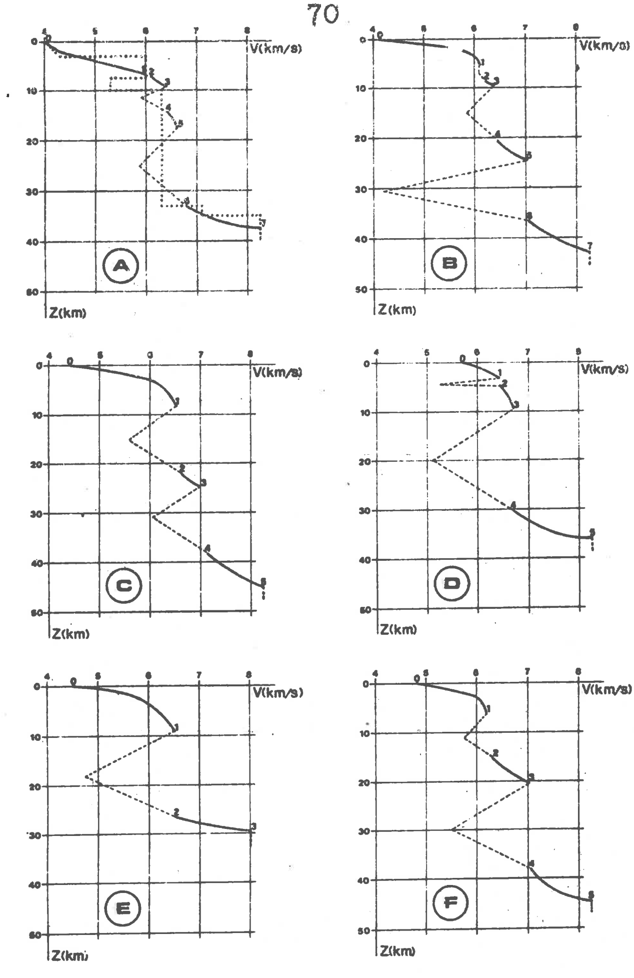


Fig. 8 — Velocity-depth functions. Numbers on the velocity functions correspond to the correlated travel-time branches. A, from S.P. A' towards the east; B, from S.P. B' towards the west; C, from S.P. B' towards the east; D, from S.P. D'' towards the northwest; E, from S.P. T towards the southeast.

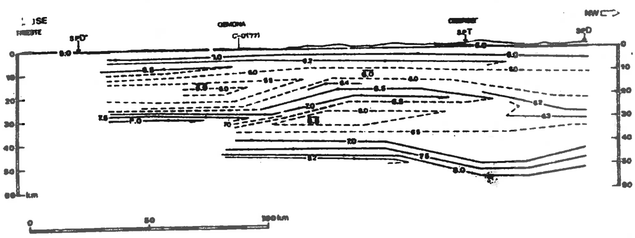


Fig. 10 — Depth section of the profile D''-T, Trieste-Obersee, 1978. See caption of Fig. 9.

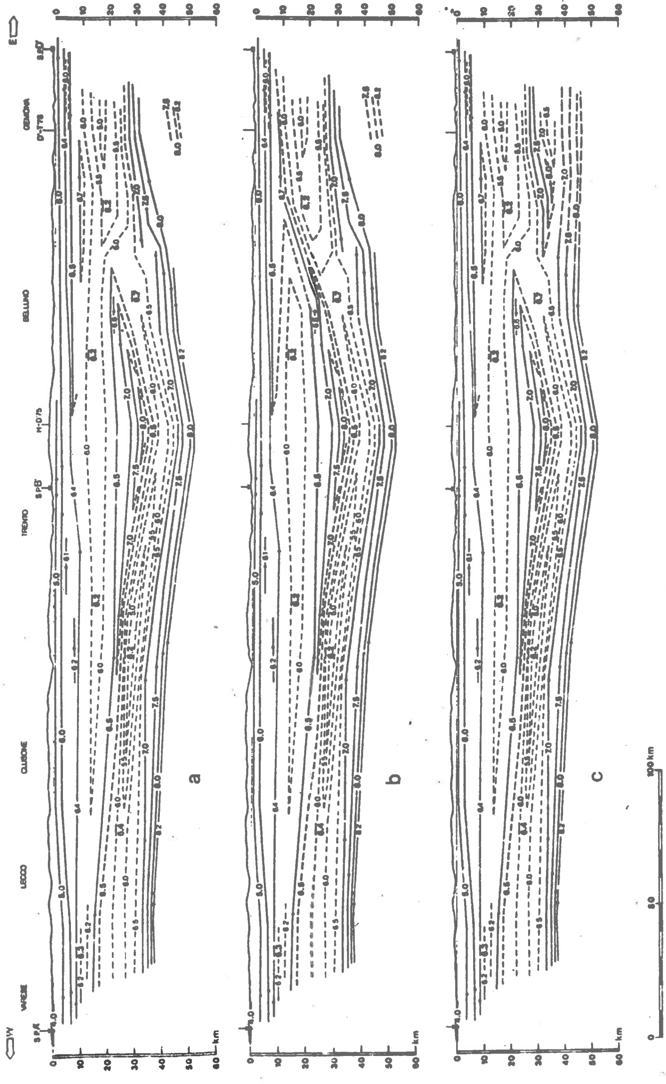


Fig. 9 — Depth section of the Southern Alps. Hypotheses a, b and c. Lines of equal velocity and values in km/s. Dashed lines indicate low-velocity layers. Overlined numbers represent average values. Dots represent the "turning points".

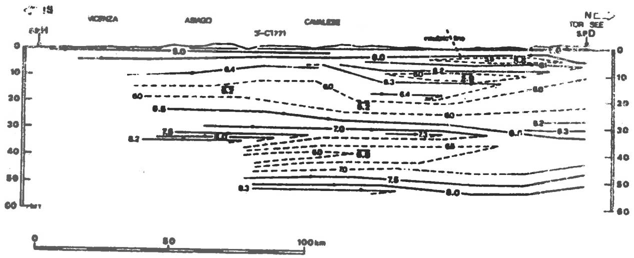


Fig. 11 — Depth section of the profile H-D, Vicenza-Innsbruck, 1975. See caption of Fig. 9.

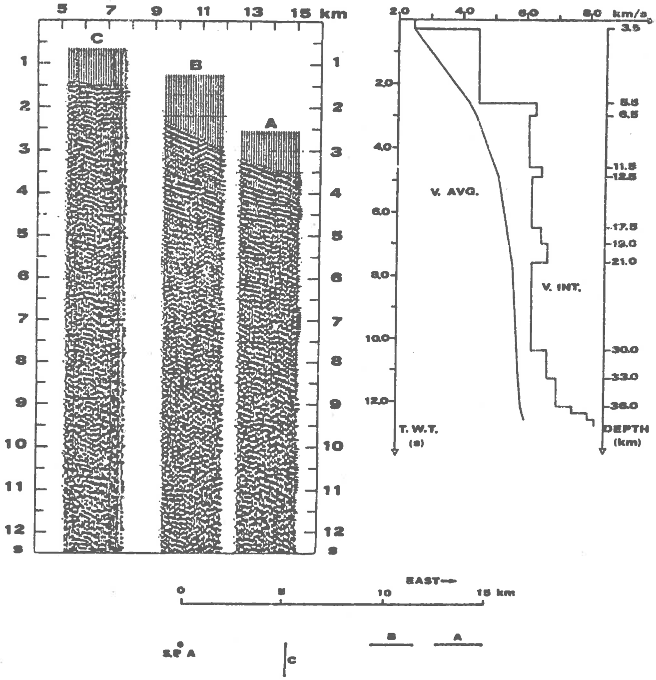


Fig. 13 — Near vertical reflections near S.P. A'-1977. A, B, C are the records obtained with the three different spread layouts located in the sketched map. Average and interval velocities are reported against reflection times and depth.

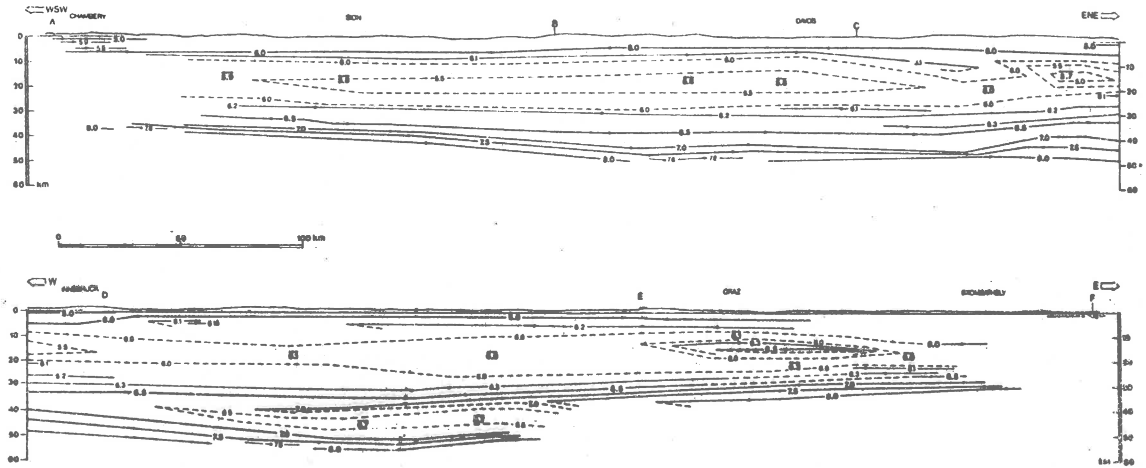


Fig. 12 — Depth section of the Central Alps-1975. See caption of Fig. 9.

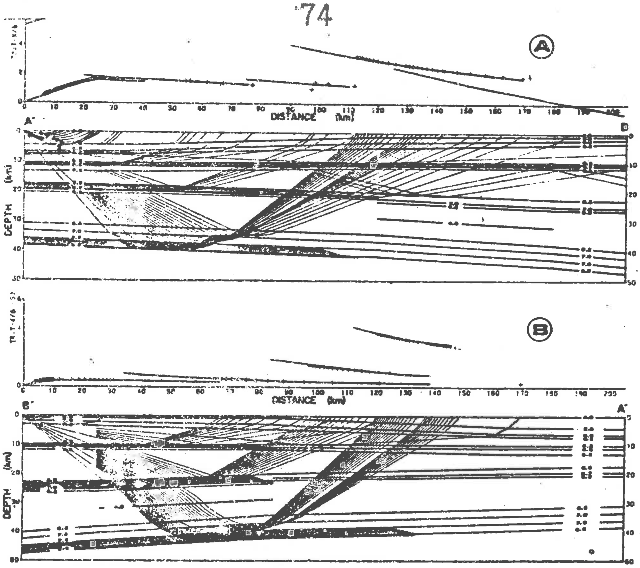


Fig. 15 — Ray-tracing model from S.P. A' to S.P. B' (A) and reverse (B), according to the depth section of Fig. 9a. Lines of equal velocity and values in km/s. Triangles represent points at horizontal tangent of the ray. Small crosses are the calculated times.

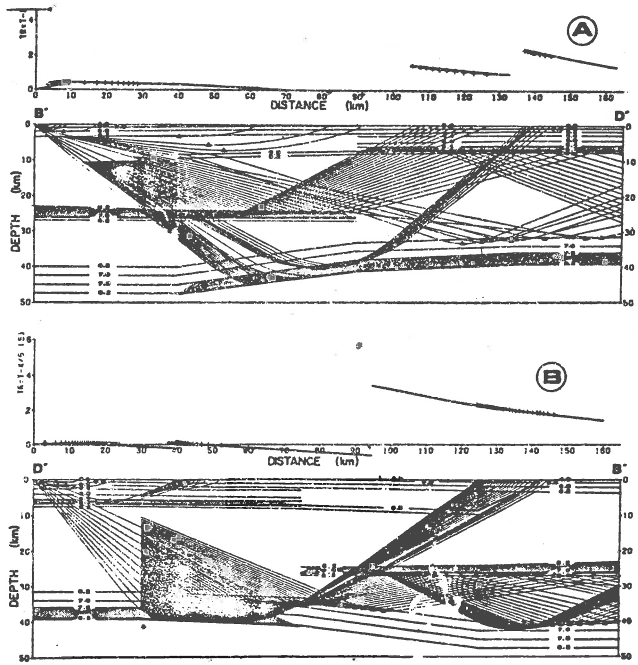


Fig. 16 — Ray-tracing model from S.P. B' to S.P. D' (A) and reverse (B). See caption of Fig. 15.

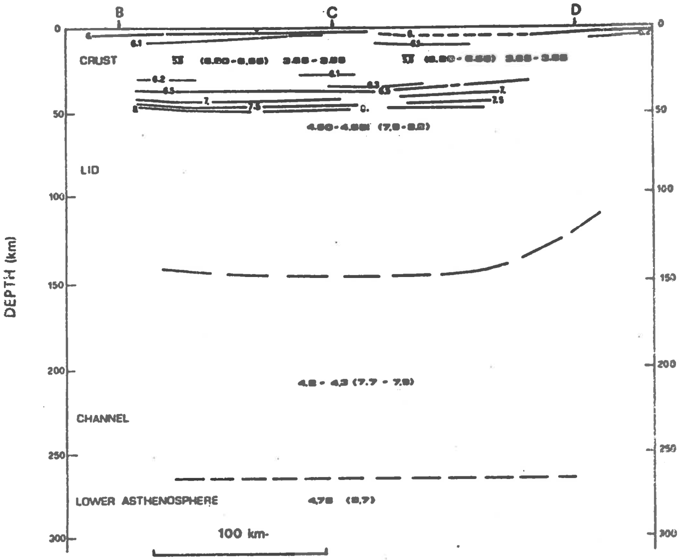


Fig. 22 — Central Alps section (B-C-D). Bold face numbers indicate *S*-wave velocity consistent with dispersion data; thin numbers the results of DSS interpretation; large size numbers average values; numbers in parentheses represent the *P*-wave velocity deduced from the *S*-wave velocity assuming a ratio $Vp/Vs \geq 1.7$. Brackets mean that the indicated *S*-wave value can be accepted only when the thickness of the corresponding layer is less than that shown in the figure.

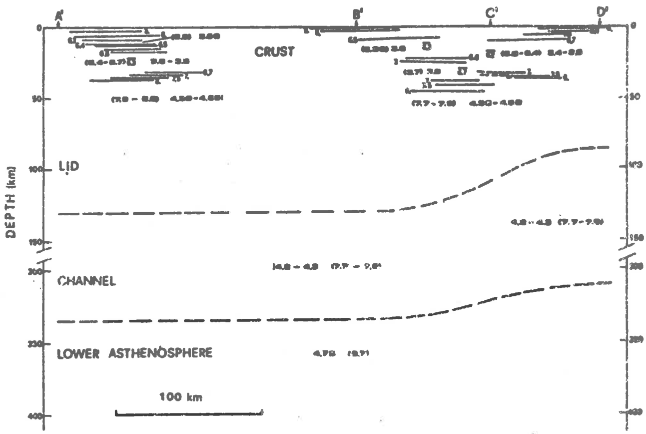


Fig. 23 — Southern Alps section (A'-B'-C'-D'). See caption of Fig. 22.

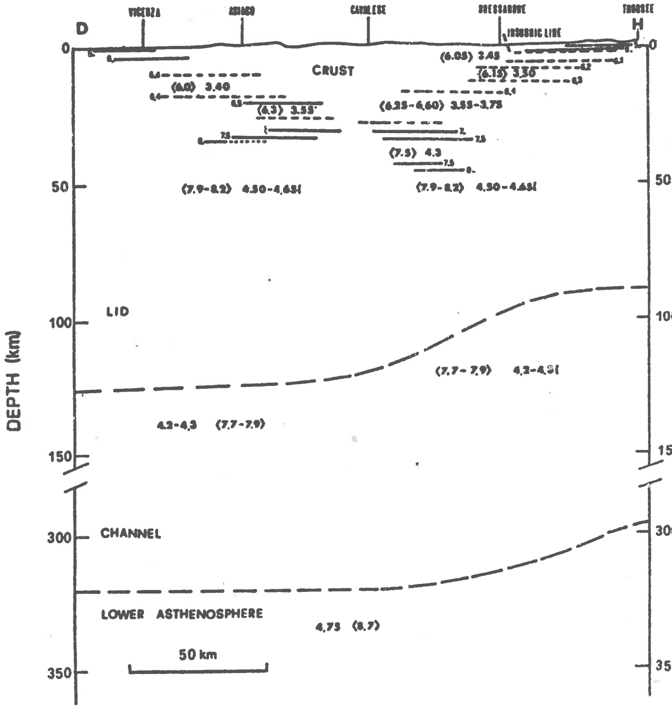


Fig. 24 — Eastern Alps section (H-D). See caption of Fig. 22.

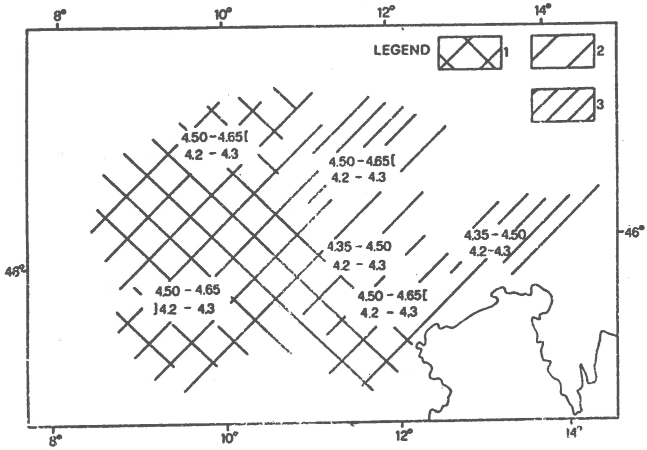


Fig. 25 — Lid characters in the Central, Eastern and Southern Alps: 1. thickness up to 105 km: 2. up to 75 km: 3. up to 45 km. Each group of numbers indicates *S*-wave velocity in the lid and in the low-velocity channel, respectively.

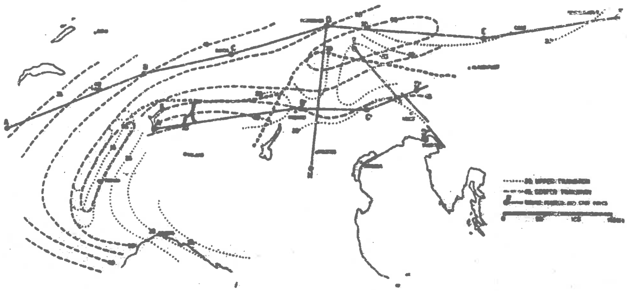


Fig. 26 — Isobathes of the main discontinuities in the Alpine region. Contour lines in km. Dashed lines refer to the deeper transition zone (crust-mantle boundary). Dotted lines refer to the shallower discontinuity. Double dashing indicates the position of the Insubric line.

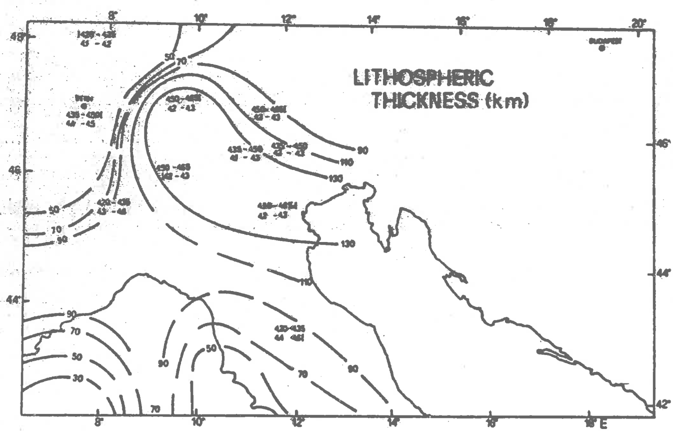


Fig. 27 — Lithospheric thickness of the investigated area (continuous lines) and surrounding regions from [7] (dashed lines).

B. 1 SARDINIA

. 2 1979.

. 3a Istituto di Miniere e Geofisica appl., Università, Trieste (C. Morelli, R. Nicolich).
Osservatorio Geofisico Sperimentale, Trieste(A.Scotti).

. 3b Institut de Physique du Globe, Université, Paris(OBS).
Institut für Geophysik, Universität, Hamburg (OBS).
Istituto per la Geofisica della Litosfera del CNR, Milano.

. 4 200 kg shots, 7 SW to Sardinia, 34 NE to Sardinia (Fig. 28), 13 Mars - 66 stations in Sardinia.

. 5 The crustal thickness of Sardinia is maximum (about 31 km) beneath the center of the profile and decreases towards the ends, amounting to 20 and 23 km beneath the SW and NE coastlines respectively. The structure of the Crust is rather simple and the transition to the adjacent seas does not show any evidence of overtrusting or interbedding.

The Bouguer anomaly field was also inverted to outline the bathymetry of the Moho beneath Sardinia.

. 6 -

. 7 Guerra I., 1981 : Struttura crostale della Sardegna sulla base di dati sismici e gravimetrici.

. 8 Fig. 28.

. 9 Figg.29 - 32.

.10 Figg. 33 - 35.

.11 -

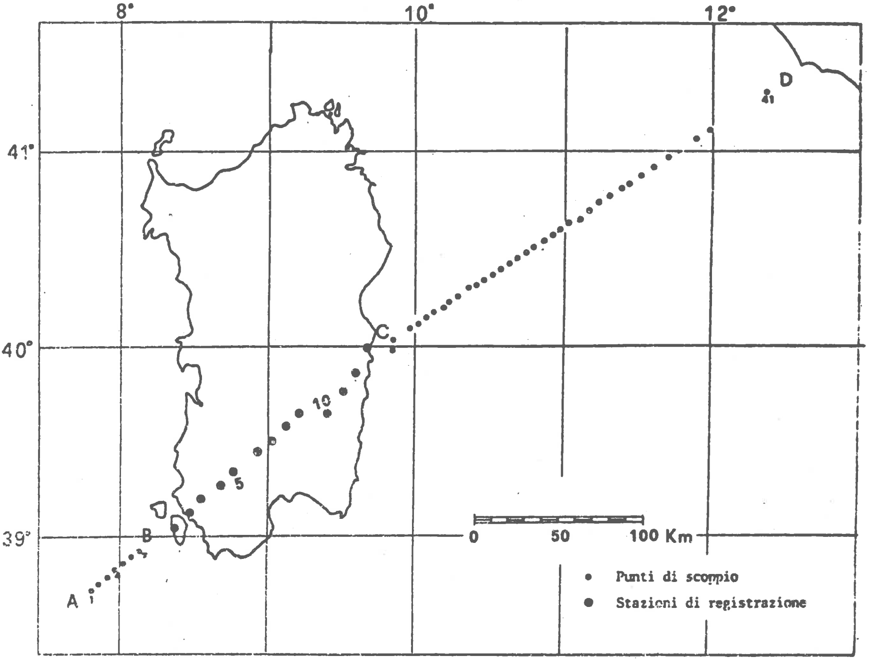


Fig. 28 - Position map with shot-points and recording stations.

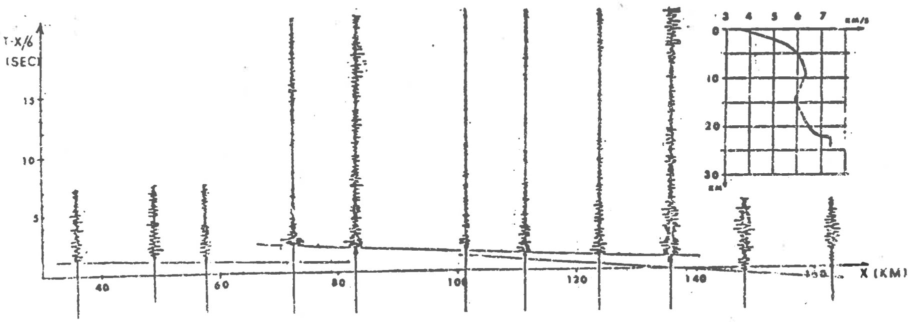


Fig. 29 - Record-section for shot-point n. 5.

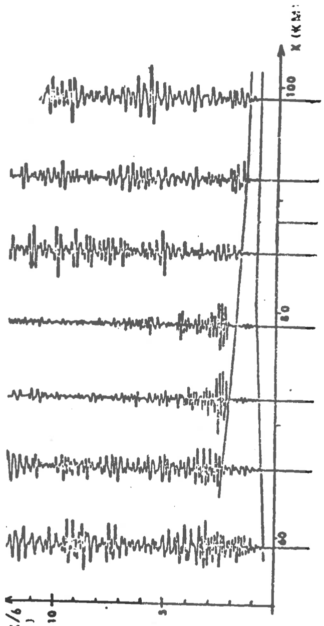


Fig. 30 - Record-section for recording station n.4 ,
Shot-points on the AB-section of the profile
(see Fig. 28).

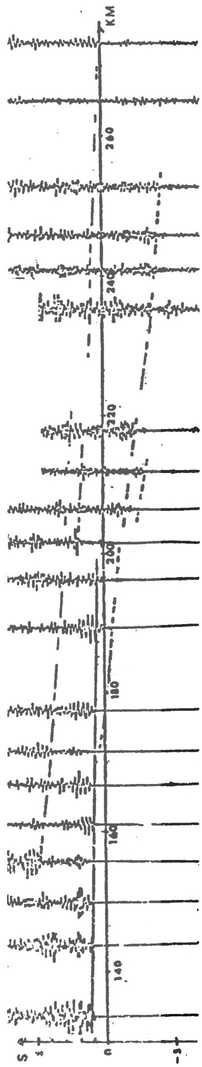


Fig. 31 - Record-section for recording station n. 4 ,
Shot-points on the CD-section of the profile
(see Fig. 28).

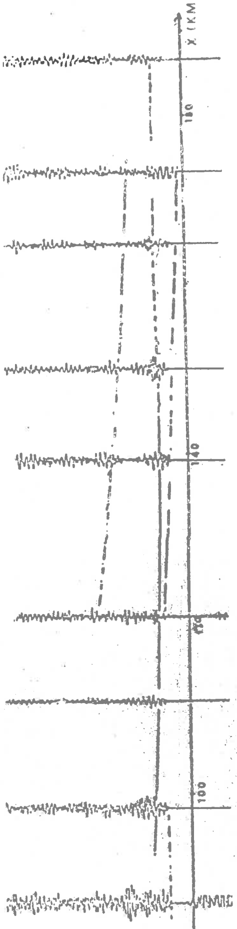


Fig. 32 - Record-section for recording station n. 11.

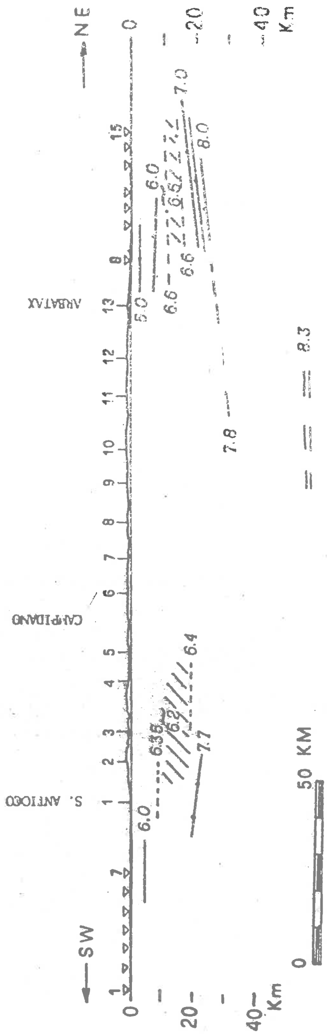


Fig. 33 - Crustal section from DSS.

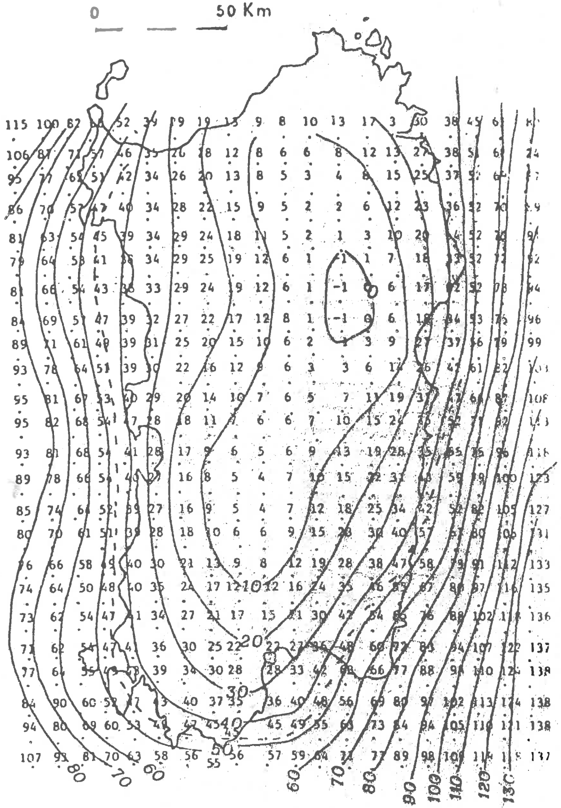


Fig. 34 - Bouguer anomaly component with wave length > 125 km.

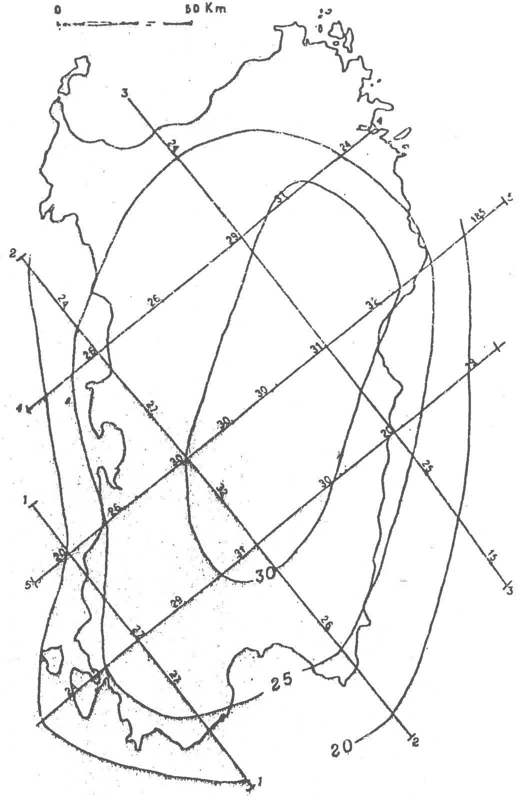


Fig. 35 - Moho isobaths (equidistance : 5 km).

C. 1 TUSCANY

. 2 1978 - 1979.

. 3a Istituto di Miniere e Geofisica appl. dell'Università, Trieste (C. Morelli, R. Nicolich).
Institut für Geophysikalische Wissenschaften der Freien Universität Berlin (P. Giese, R. Wigger).

. 3b Osservatorio Geofisico Soerimentale, Trieste(A.Scotti).
Istituto per la Geofisica della Litosfera,CNR,Milano (S. Scarascia).
Osservatorio Vesuviano, Ercolano, Napoli (I. Guerra, G. Luongo, R. Scarpa).
Istituto di Scienze della Terra, Università di Catania (M. Cosentino).
Istituto di Fisica, Università di Lecce (M.T.Carrozzo, D. Luzio).

. 4 Refraction seismic measurements were carried out in July 1978 and 1979 in Tuscany and Latium with the goal to receive the crustal and upper mantle structure and the velocity distribution in the geothermal anomaly of Tuscany.

. 5 The main results are : The Crust of Tuscany is thin. On reason of the relative high velocity and the missing of distinct velocity inversions it must be excluded that a greater extent of molten material in the upper crust could be found. However, the transition zone to the upper mantle shows layers of extreme low velocity, at least temperatures of 600-700° C have to be expected in this region.

Besides, in the transition zone under the area of Larderello a jump of 6-7 km to the upper mantle was found, possibly corresponding to the jump in the basement of that region.

Model calculations which were made for the temperature distribution in this area were discussed.

. 6 -

. 7 Giese P., Morelli C., Nicolich R., Wigger P., 1980 : "Seismic studies for the determination of the crustal structure in the area of the geothermal anomaly in Tuscany".
Istituto Miniere e Geofisica appl., Università, Trieste; Contrib. n.47.

. 8 Fig. 36.

. 9 -

. 10 Figg. 37 - 38.

. 11 -

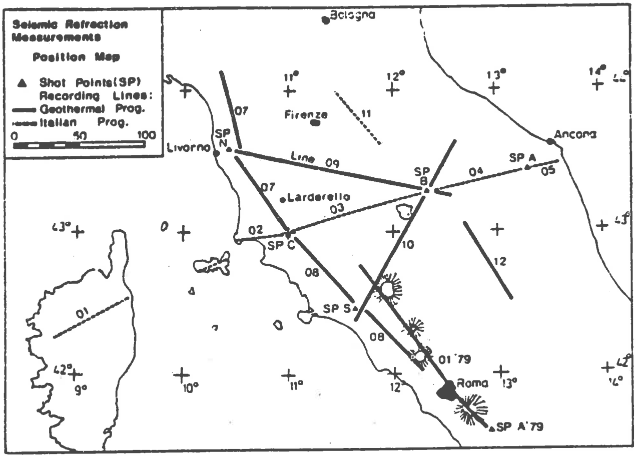


Fig. 36 - Position map of the field measurements 1978/79.

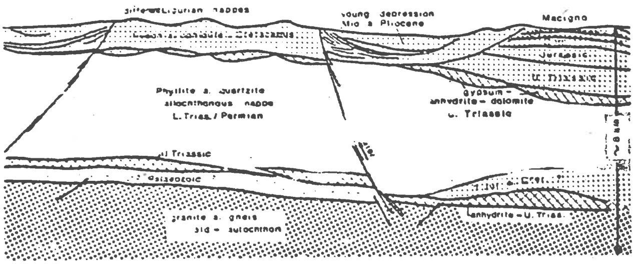


Fig. 38 - An idealized model of the near surface structure.

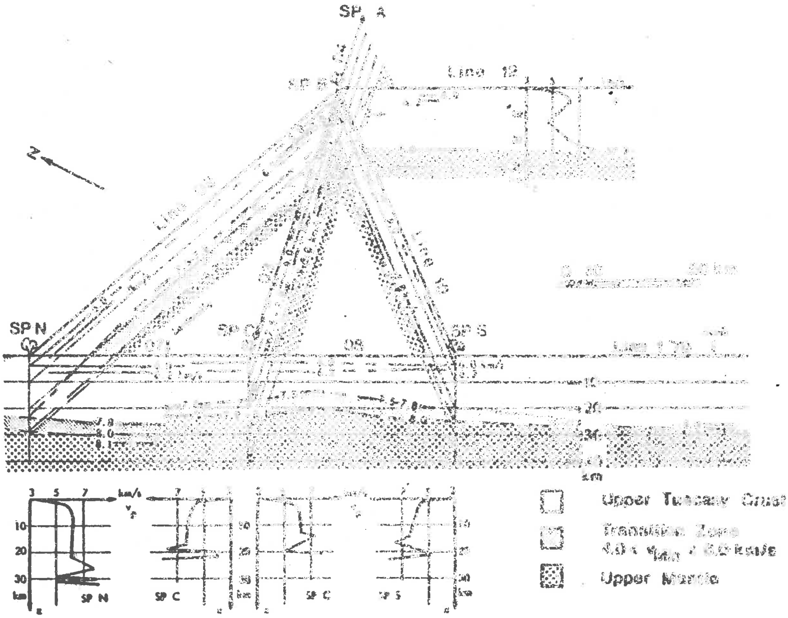


Fig. 37 - The seismic model of the Tuscany crust.

D. 1 Tyrrhenian Sea and Tuscany.

. 2 1979 - 1980.

. 3a Istituto di Miniere e Geofisica applicata, Università di Trieste (C. Morelli, R. Nicolich).
Osservatorio Geofisico Sperimentale, Trieste (A. Scotti).

. 3b Institut für Geophysik, Universität, Hamburg (OBS)
Gruppo Italiano Esplosioni.

. 4 Two deep seismic profiles running from Sardinia to Pescara and from the Tyrrhenian bathyal plain to the Campanian coasts are presented. The data have been obtained by the employment of OBS offshore and mobile recording stations on land.

. 5 The first profile reveals well diversified crustal structures: crustal thinning in correspondence of the central Tyrrhenian Sea, a peculiar lower Crust configuration toward the Latial coasts that can be correlated to the crustal models of the geothermal region of Tuscany, and a continental Crust characteristic of the Adriatic margin from Anzio to Pescara.

The 2.nd profile, explored by higher resolution techniques, evidentiates a very thin Crust in correspondence of the Thyrrenian bathyal plain and points out the fine structure of the Crust-Mantle boundary towards the Campanian coasts.

. 6 -

. 7 Nicolich R., 1981 : "Il profilo Latina-Pescara" e le registrazioni mediante OBS nel Mar Tirreno". Istituto di Miniere e Geofisica applicata, Università di Trieste; contrib. n. 64.

. 8 Fig. 39.

. 9 Figg. 40 - 43.

.10 Figg. 47 - 49.

.11 -

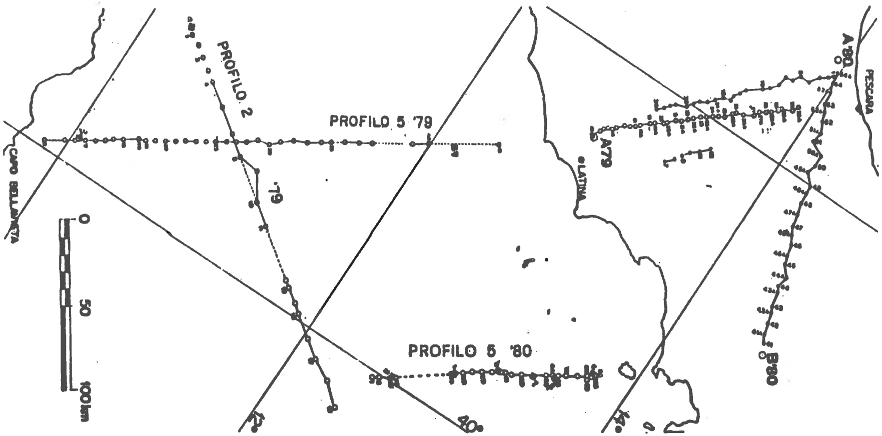
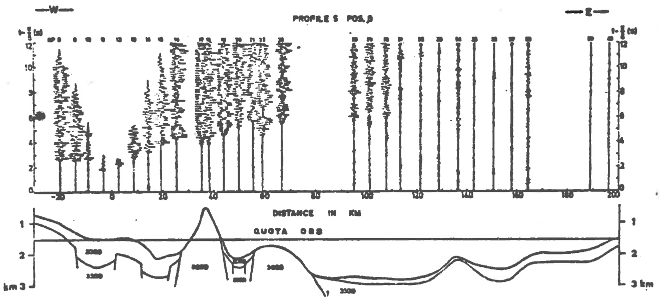


Fig. 39 - Position map with shot-points on sea and on land, of the OBS and of the recording stations on land.



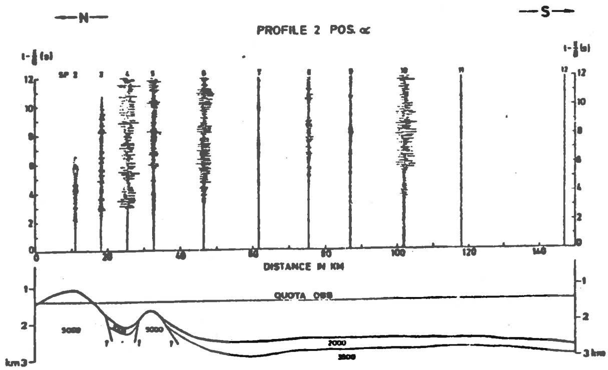


Fig. 40 - Record-section for OBS β and α and scheme of the near-bottom structures from reflection seismics.

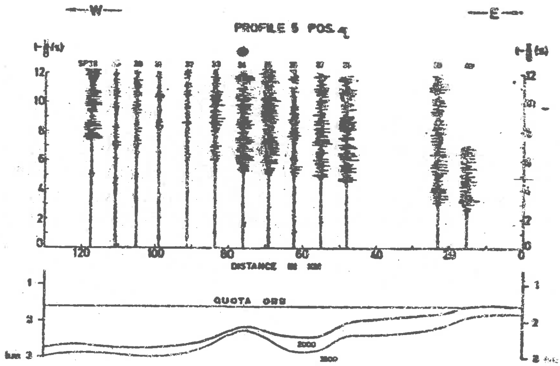


Fig. 41 - Record-section for OBS η.

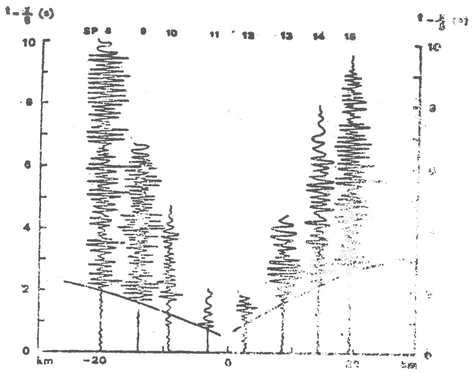


Fig. 42 - OBS β, near-shots after reduction to a reference-plain at - 1520 m below sea level (OBS depth) and proposed correlations.

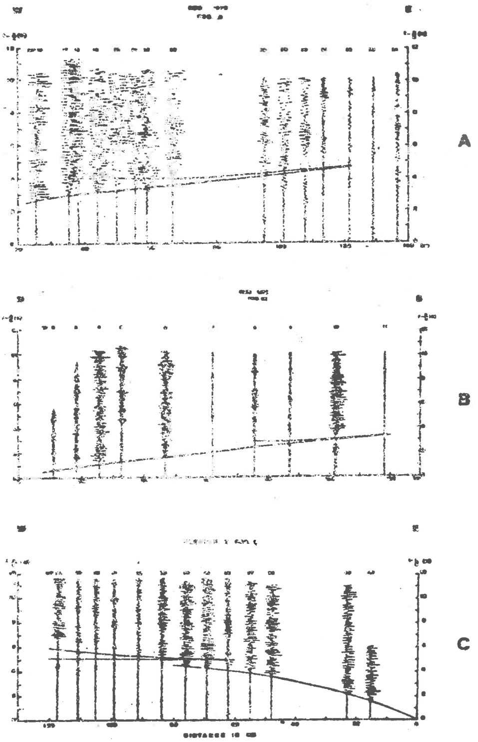


Fig.43 – A) OBS- β , distant-shots after reduction to a reference-plain at - 3000 m.
B) OBS - α with reference plain at - 3000 m.
C) OBS - η with reference plain at - 1600 m.

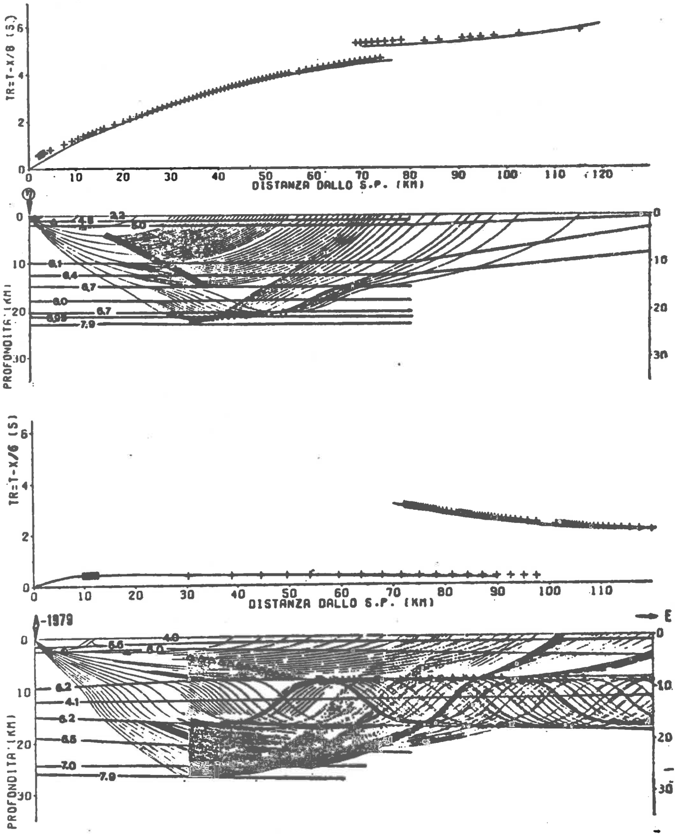


Fig. 47 - OBS η and shot-point A-1979. The reference plain for η is - 1600 m; for A-1979 it coincides with the topographic surface.

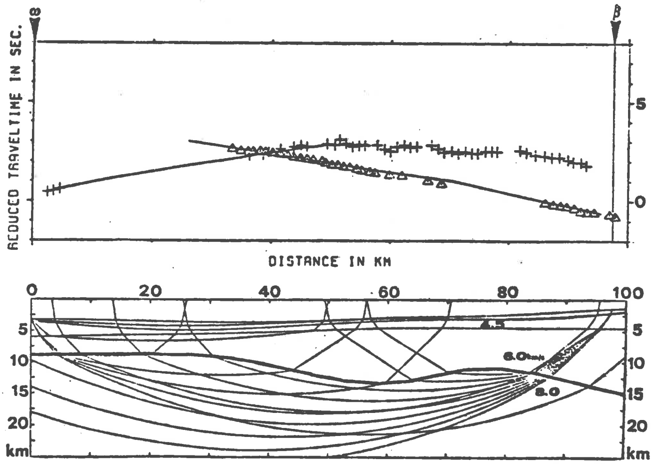


Fig. 48 - "Ray-tracing" for the profile 5-1980 (from OBS - ω to OBS- β).

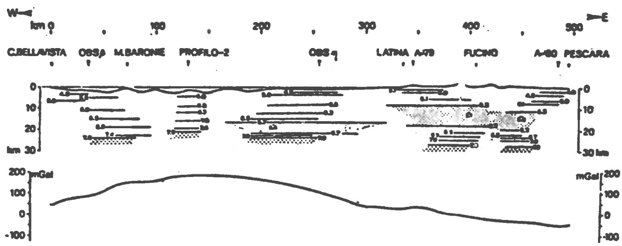


Fig. 49 - Synthesys of the crustal data on the Sardinia - Pescara profile and Bouguer anomalies.

E. 1 OUTER CALABRIAN ARC.

. 2 1979.

. 3a Istituto di Miniere e Geofisica applicata, Trieste (C. Morelli, R. Nicolich)
Osservatorio Geofisico Sperimentale, Trieste (A. Scotti).

. 3b Institute de Physique du Globe, Université Paris 6 (OBS).
Institut für Geophysick der Universität, Hamburg (OBS).

. 4 45 Shots in the Jonian sea, 13 land recording stations in Calabria.

. 5 In correspondence of Calabria a discontinuity exists between the Moho in the Tyrrhenian and in the Jonian areas.

. 6 -

. 7 Linari R., 1981 : " DSS 1979: Interpretazione preliminare del profilo Calabria - Mar Ionio". Istituto di Miniere e Geofisica appl., Università di Trieste, Contrib. n. 52.

. 8 Fig. 50.

. 9 Figg. 51 - 52.

.10 Figg. 53 - 56.

.11 -

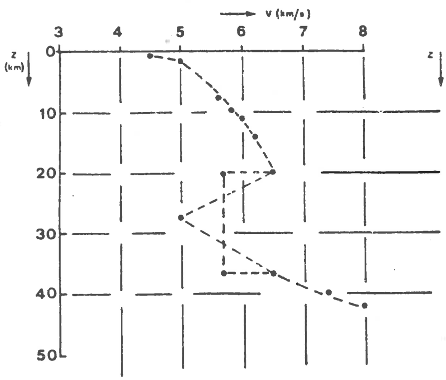


Fig. 54 - Calabria SE : velocity/depth function.

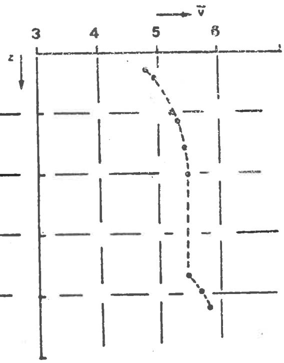


Fig. 55 - Mean velocity function

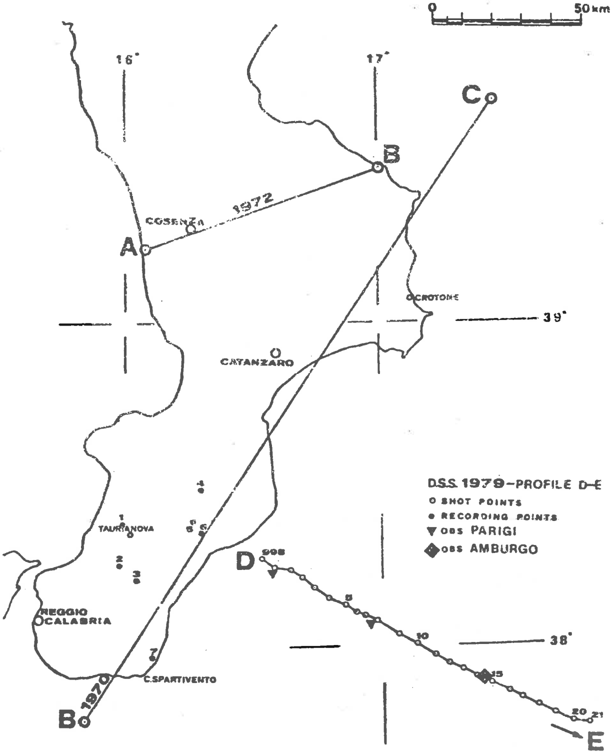


Fig. 50 - Position map of the profile D-E(DSS79); A-B(DSS72); B-C(DSS70)

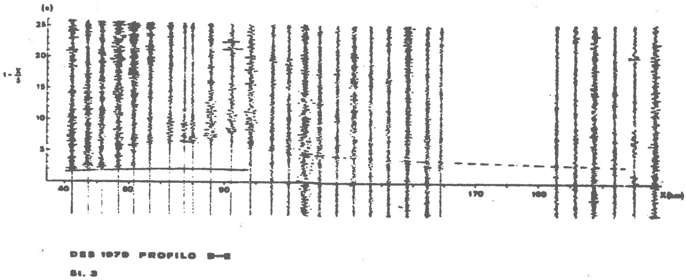


Fig. 51 - Example of record section (reduced travel times : v_r = 6.0 km/s.

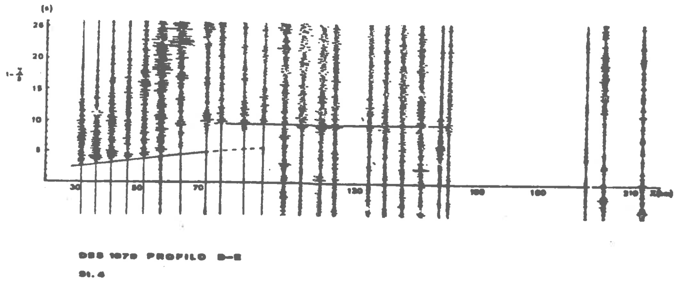


Fig. 52 - Example of record section (reduced travel times : v_r = 8.0 km/s).

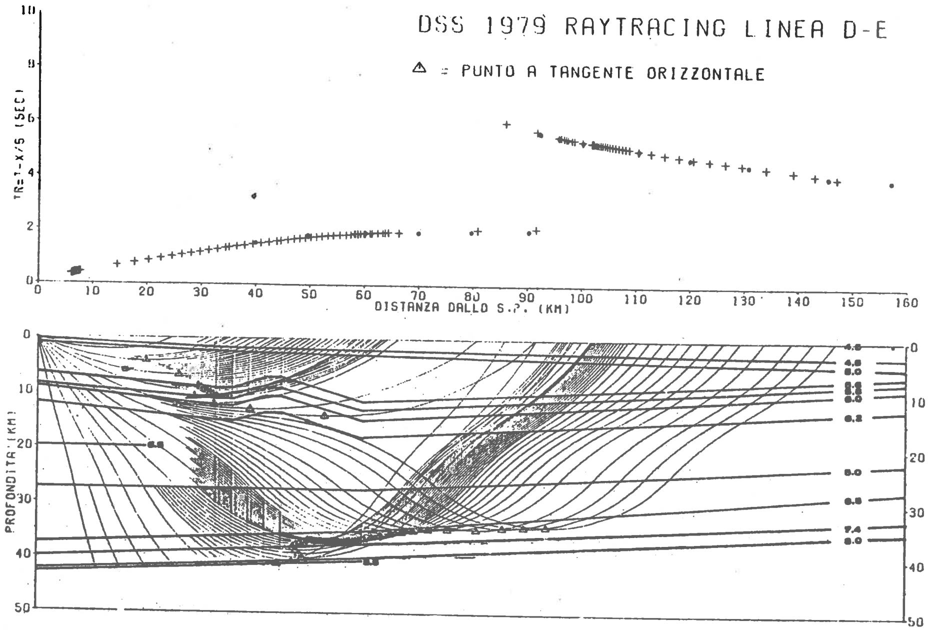


Fig. 53 - Ray-tracing model for the profile D-E.

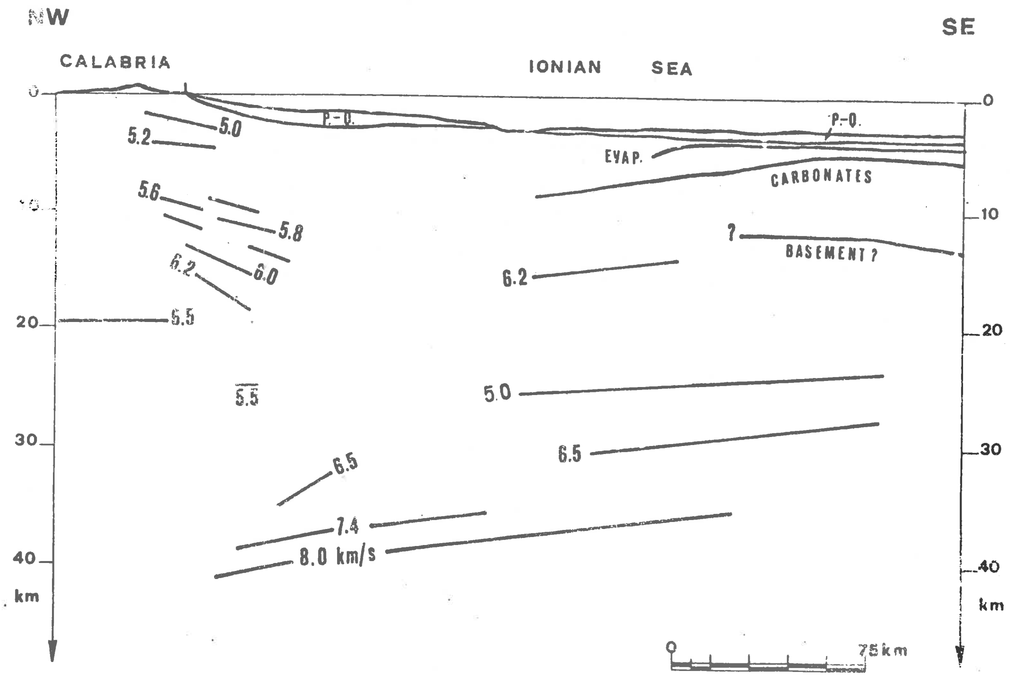


Fig. 56 - Profile D-E : depth section integrated with seismic reflection data.

F. 1 CRUSTAL STRUCTURES IN THE ITALIAN PENINSULA AND SURROUNDING SEAS : A REVIEW OF DSS DATA by R. Nicolich, Istituto di Miniere e Geofisica appl. n. 60, 1981.

ABSTRACT. The Italian Peninsula lies within the alpine orogenic belt considered in the Plate Tectonic model as the suture zone marking the closure of the Tethys ocean. Systematic geophysical investigations and extensive seismic crustal studies are bringing a significant contribution in revealing the crustal and Upper Mantle structures in this area. The different models proposed to explain the present geological features and the geophysical evidences are now under discussion. This review refers to the main results aiming to discuss the most important features of the crustal structures of the sorrounding seas of the Italian Peninsula: Provençal basin and Ligurian Sea, Tyrrhenian Sea and its coastal regions, Pelagian, Ionian and Adriatic Seas.

Figg. 57 - 69.

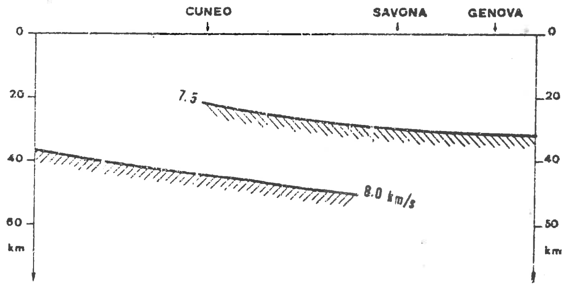


Fig. 57 : Crustal sketch between western Alps and Northern Apennines along the DSS profile Lac Negre - Genova.

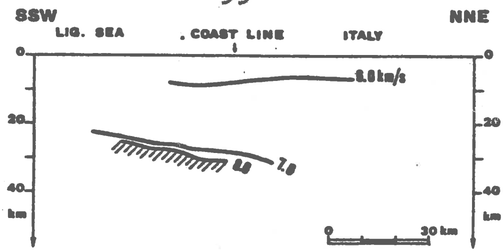


Fig. 58 : Moho trend from the Ligurian Sea to Chiavari.

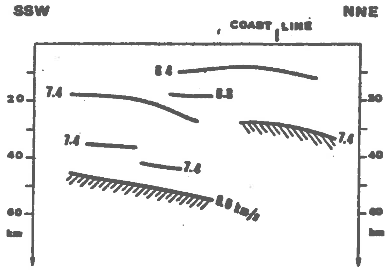


Fig. 59 : Moho trend from the Ligurian Sea to La Spezia.

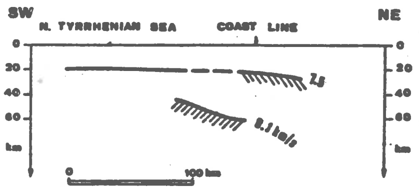


Fig. 60 : Moho trend from the Northern Tyrrhenian Sea to Viareggio.

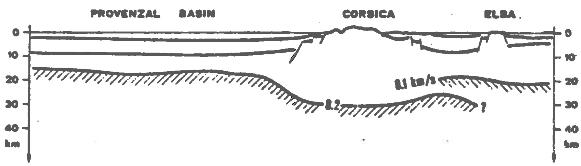


Fig. 61: Crustal sketch from the Provenzal Basin to Corsica and Elba.

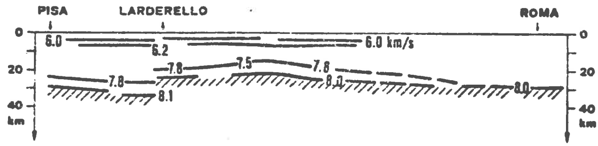


Fig. 62 : Crustal sketch from a DSS profile from Pisa to Rome.

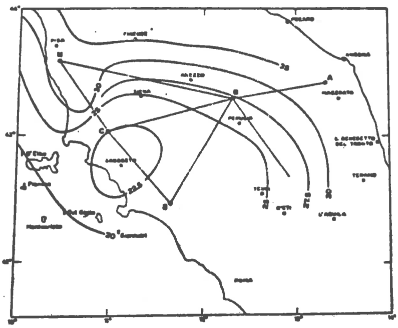


Fig. 63 : Moho isobathes (km) in Tuscany.

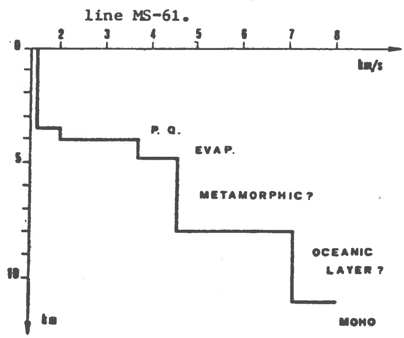


Fig. 64 : Sonobuoys data in the bathyal plain of the Tyrrhenian Sea.

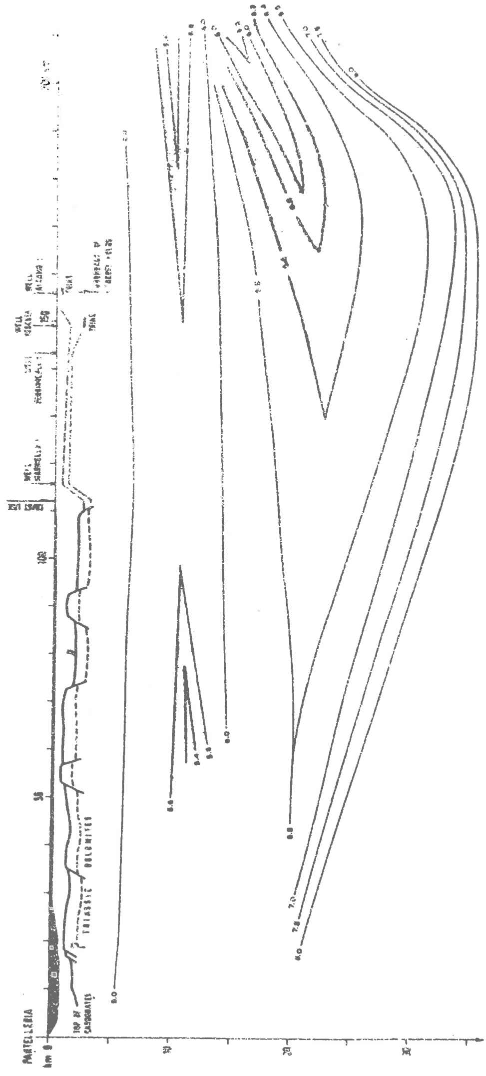


Fig. 65 : Cross-Section between Pantelleria and Palermo.

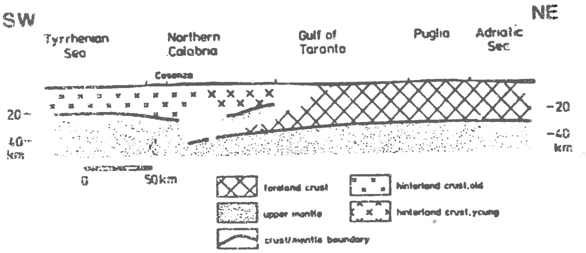


Fig. 66 : DSS data from Eolian Islands to Apulia through North Calabria.

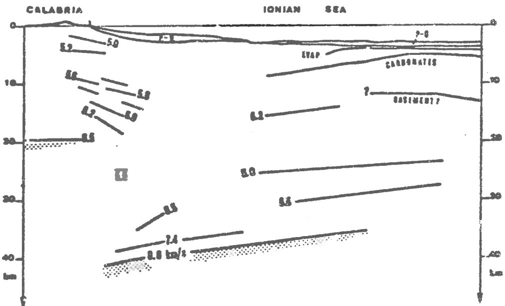


Fig. 67 : From Ionian Sea to Calabria (Aspromonte).

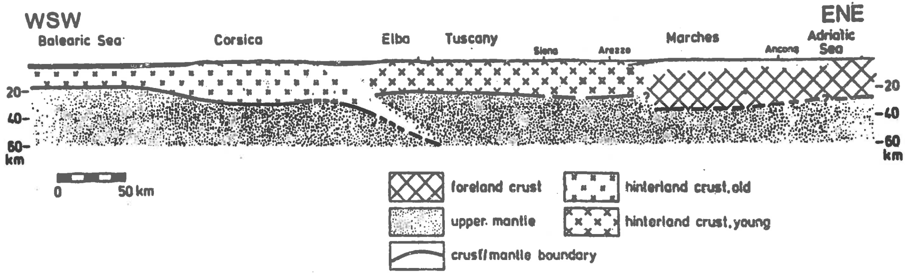


Fig. 68 : Scheme of a Cross-Section between the Balearic and Adriatic Seas, passing Corsica, Elba and Tuscany.

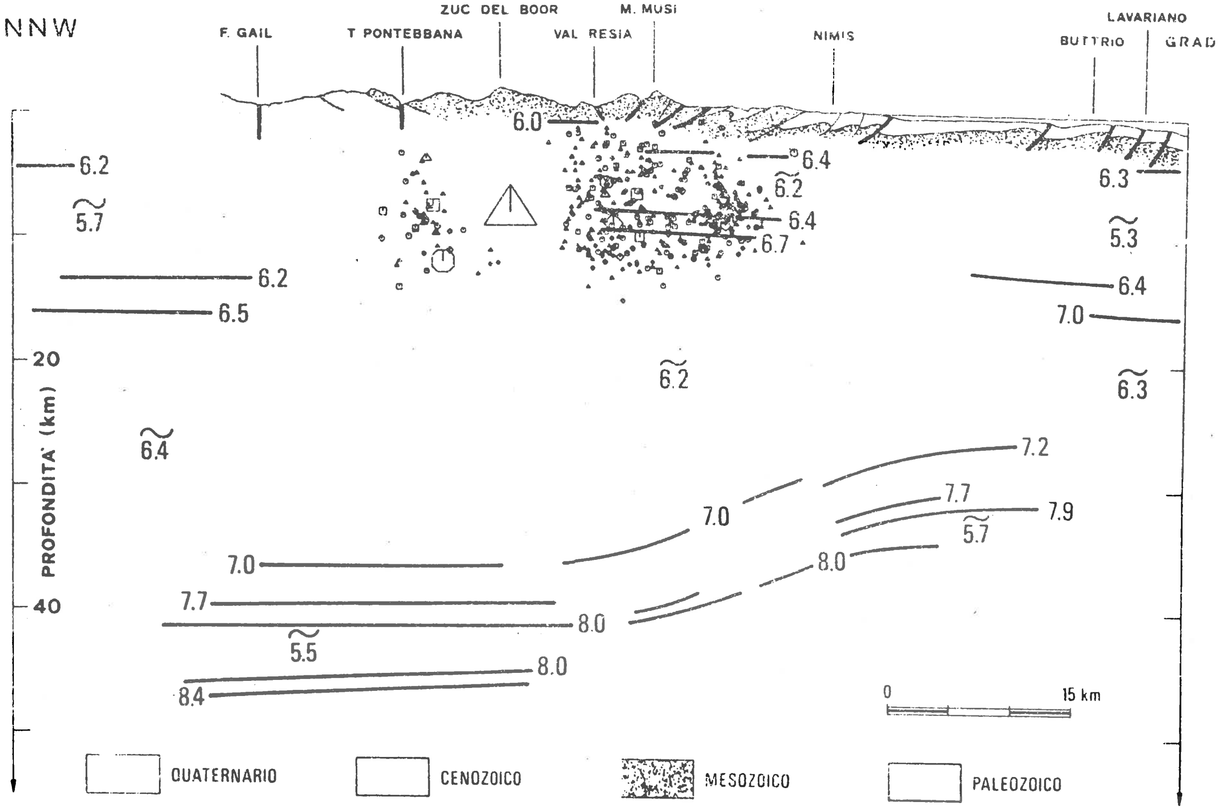


Fig. 69 - Schematic seismic model for a profile from Grado to the austrian border.

NORWAY (NORSAR, Kjeller; dr. Svein Mykkeltveit)

1. CANOBE (CAmbridge-NOrsar-BErgen)

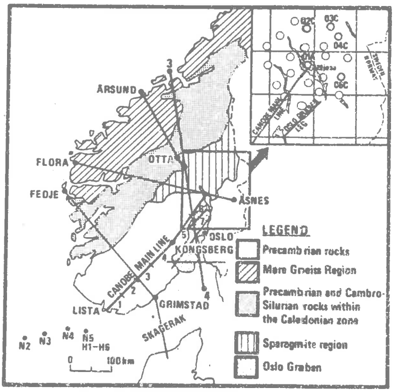
2. 27 July - 4 August 1980

3. University of Cambridge (Cassell)
   NORSAR (Mykkeltveit, Husebye)
   University of Bergen (Kanestrøm)

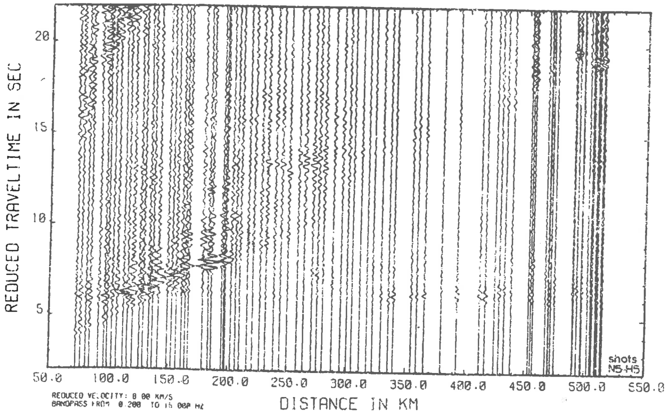
4. During shots N2-N5, field stations occupied permanent positions along leg 1. For subsequent shots H1-H6, stations were moved along the line (legs 2-7). Average station spacing was 5 km.

5. 2-D modelling of travel times and amplitudes proved invaluable in explaining observational characteristics. The Moho appears to 'sink' beneath the coast from 27 km on the sea side to 34 km onshore. Large Pg amplitudes imply a strong velocity gradient in the lower crust. Comparison of travel times inside (leg 7) and outside the Oslo Graben (legs 5 and 6) suggests an elevated Moho in the Graben.

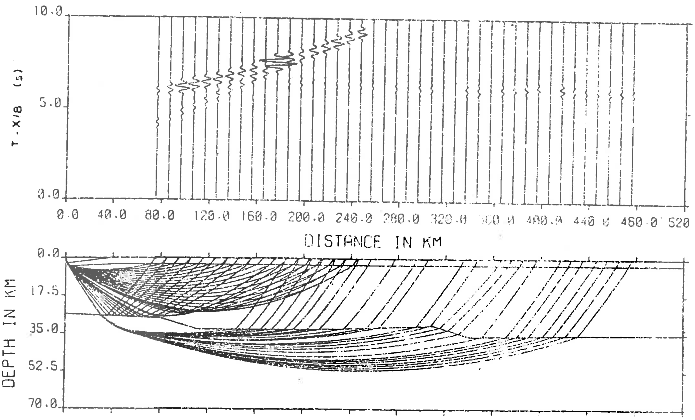
7. Cassell, Mykkeltveit, Kanestrøm and Husebye: 'A North Sea-southern Norway seismic crustal profile'. Submitted for publication.



Map showing shot points and CANOBE recording legs. Previous profile lines in southern Norway are also shown.



Normalized record section for CANOBE main line. Amplitudes are multiplied by distance.



Synthetic seismograms for the laterally varying structure (bottom). Note the large amplitude at about 180 km, matching observed ones.

POLAND (Institute of Geophysics, Polish Academy of Sciences; prof. A. Guterch)

1. SEISMIC REFRACTION AND REFLECTION INVESTIGATIONS OF THE WEST ANTARCTICA BETWEEN 61° AND 65° S AND 65° AND 66° W

2. January and February 1980.

3a. The Polish Geophysical Expedition to the West Antarctica in summer 1979/80 was organized by the Institute of Geophysics of the Polish Academy of Sciences.

3b. Prof. A. Guterch, Dr. M. Grad, Dr. J. Pajchel and Dr. E. Perchuć.

4a. Shots were fired in the sea at the depth of 70-80 m along DSS profiles. The distance between shot points was 3 to 5 km. Altogether 150 shots were made. The charges were not larger than 50 kg of dynamite (exceptionally 100 kg only). The records were obtained on land using 3-channel seismic refraction instruments. Altogether about 500 seismic records of high quality were obtianed, at distances from a few to 280 km from shot points. Deep seismic soundings were made along profiles of total length about 2200 km. Altogether seismic reflection measurements were made along the profiles about 1100 km long. An extensive programme of magnetic studies was executed along profiles about 2000 km long.

4b. Geophysical equipment and instruments:

a) Research Vessel "Kopernik", 1600 BRT
b) DFS-IV marine multi-channel seismic system and air-gun Bolt system installed on the R/V "Kopernik".
c) 3-channel seismic refraction land stations
d) Marine magnetometre

Localisation: DSS-profiles, reflection and magnetic profiels, shot points - see Figure 1.

5. The purpose of the expedition was to carry out studies of deep structures of the Earth's crust and lower lithosphere by several geophysical methods, within the general programme of geodynamic studies of the West Antarctica. A special attention was paid to tectonically active zones and to contact zones between the blocks of the Earth's crust and lithospheric plates. The measurements covered the Southern Shetlands, Antarctic Peninsula, Bransfield Strait, Drake Passage, Palmer Archipelago, Gerlace Strait and Bismarck Strait towards the Southern Pacific.

Along deep seismic sounding profiles the following wave groups were recorded and interpreted:

a) refracted waves from the crystalline basement with boundary velocities 6.0 to 6.4 km/s indifferent blocks of the Earth's crust,
b) refrected and reflected waves from the discountinuity interpreted as the upper boundary of the transition zone between the crust and upper mantle (7.3-7.7 km/s), in the region of tis occurrence,
c) refrected and reflected waves from the Moho discountinuity and reflected waves from the boundary occurring in the lower lithosphere near the Moho discountiunity.

On some profiles unusually intensive S waves, besides P waves, were recorded. For example, amplitudes of the reflected S waves from the Moho discountinuity (S^MS) are even twice higher than amplitudes of the reflected P^MP waves. In particular, the structure of the S waves field for profiles located along geological structures is identical with the pattern of the decribes P waves.

In general, detailed analysis of the seismic wave field shows that the structure of the Earth's crust in this part of West Antarctica is very complicated. Numerous deep fructures divide the Earth's crust in blocks of different physical properties.

The seismic reflection measurements were mainly concentrated on the shelf of the Antarctic Peninsula in the axial part of Bransfield Strait and on the shelf of the Shetland Islands from the side of Drake Passage. Very interesting are reflection sections from the profiles crossing the shelf of the Shetland Islands and an oceanic trench about 5500 m deep in Drake Passage (Figure 4.).

A geodynonical model of this part of the West Antarctica, related to previous geophysical and geological investigations, will be the final result of undertaken studies.

6. Continuation of this project is planned 1984/85.

7. General reports only. Publications in preparation.

8. See Figure 1.

9. See Figure 2, 3 and 4.

Institute of Geophysics, Polish Academy of Sciences

1. DEEP SEISMIC SOUNDING OF THE EARTH'S CRUST ON THE SVEKA PROFILE IN FINLAND

2. June 2-12, 1981

3. Institute of Seismology, University of Helsinki
Dept. of Solid Earth Physics, University of Uppsala
Institute of Geophysics, Polish Academy of Sciences
Dept. of Geophysics, University of Oulu,
Geological Survey of Finland, Espoo

4-11. In summer 1981 field measurements were carried out on the SVEKA profile by participants form Finland, Poland and Sweden. Exactly informations - see Activity Report 1980-82, Finland.

1. DEEP SEISMIC SOUNDINGS OF THE EASTH'S CRUST IN POLAND

1a. Seismic refraction studies of the south-west margin zone of East European Plotform in Central Poland (LT-6 Profile)

2. July/August (4 weeks), 1981

3a. Prof. A. Guterch, Dr. J. Pajchel and Dr. E. Perchuc'
Institute of Geophysics, Polish Academy of Sciences

3b. S. Toporkiewiez
Geophysical Enterprise of Oil Mining, Cracow

4, The total length of LT-6 profile was obout 500 km. Distances between shot points were about 60-70 km. Refraction seismic measurements were carried out manily by the continuous profiling method. Shooting works were carried out in 4 shot points along of midle part of LT-6 profile in boreholes of 30-40 m deep. Distances between geophones were 200 m. The measurements were usually made up to distance of 220 km. The location of the LT-6 profile is presented in Fig. 5.

5. Deep seismic soundings carried out along regional profile LT-6 are part of the general project of seismic studies of the Earth's crust and upper mantle in the marginal zone of the East European Precambrian Plotform in Poland. One of the major tectonic problems in Europe is determination of the south-west margin of East European Platform in Poland and North Germany. South-west boundary of the East European Plotform is not clear, because the basement is there deeply hidden under a thick sedimentary cover. In general, this margin is assumed to be the Teisseyre-Tornquist tectonic zone running approximately from NW to SE in this part of Europe. Teisseyre-Tornquist tectonic zone is about 50 to 85 km wide. T-T tectonic zone has tectonophysical properties quite different from those of the adjacent crustal blocks. In this zone two distinct seismic discontinuities occur in the lower crust at depth of about 40-45 km and 50-55 km. Strong reflected waves from these two discontinuities and some refrected waves were observed. The velocity of the refracted waves for these discontinuities were about 7.5-7.7 and 8.3-8.4 km/s respectively. The depth of the consolidated basement in north-west region of the T-T zone is about 12 km. Results of deep seismic soundings suggest that T-T tectonic zone is actually and old hidden graben with intra continental rift properties. This zone has fundamental importance for the determination of a geodynamical model of the south-west margin zone of the East-European Plotform (see enclosed Figures 6 and 7). The first results from LT-6 profile confirmed data from other DSS profiles.

6. Seismic measurements along LT-6 profile will be continuation in 1982.

7. In preparation.

8. Figure 5.

10. Figures 6 and 7.

1b. Seismic refraction studies of the south-west margin zone of East European Plotform in south-east Poland (LZW Profile)

2. October/Nowember, 1980

3a. A. Guterch, M. Grand and R. Materzok
Institute of Geophysics, Polish Academy of Sciences
University of Warsaw

3b. S. Toporkiewiez
Geophysical Enterprise of Oil Mining, Cracow

4. The total length of LZW profile was about 200 km. The location of the LZW profile is presented in Fig. 5. Distances between shot points were about 60 km. Seismic measurements were carried out by the continuous profiling method from four shot points. The shots were carried out in boreholes of about 30 m deep. The measurements were usually made up to distance of about 200 km.

5. The tectonic situation of south-east Poland is particularly complex. In this region, three different tectonic units intersect: 1) the East European Precambrian Plotform, 2) the Teisseyre-Tornquist tectonic zone (= the marginal zone of the East European Plotform) and 3) Alpine system represented by the Carpathian foredeep. To the west from this "tectonic loop" there emerges a Paleozoic Massif of the S'wigtokrzyskie Mts. In the region of the Teisseyre-Tornquist tectonic zone, the Moho discontinuity is at a depth of about 55 km. A large deep fracture zone, in which it is very difficult to determine the Moho discoutinuity was found. The most effective seismic boundary is a discontinuity encountered at a depth of some 60 km.
Aim of the project was detailed investigate of the structure of the Earth's crust in contact zones between the Precambrian Plotform, the T-T tectonic zone and Carpathian foredeep.

6.

7. Publication in preparation.

8. Figure 5.

10. Figure 6 and 7.

1c. Seismic refraction investigations of the Paleozoic Plotform of Central and Western Europe in Poland (M-13 Profile)

2. 1978.

3a. M. Grad, A. Guterch, R. Materzok, E. Perchuc'
Institute of Geophysics, Polish Academy of Sciences
University of Warsaw

3b. S. Toporkiewiez
Geophysical Enterprise of Oil Mining, Cracow

4. The basic material for M-13 Profile are seismic recordings obtained in the 1979 by the Geophysical Enterprise of Oil Mining with the aim to study the consolidated basement and shallower boundaries connected with the old Paleozonic formations. The measurements were usually made up to distance of 80-100 km from shot points. The distances between the shot points were approximately 10-25 km. The recording was carried out with the use of typical industrial multichannel refraction stations with low-fregnency geophones (2-3 Hz). The length of M-13 Profile was about 200 km (Fig. 5).

Institute of Geophysics, Polish Academy of Sciences

1. FENNOLORA

1a. Baltic See - Black See Geotraverse

2. 4 shots - 1978 (SP 3 and 4)
   7 shots - 1979 (SP 1, 2 and 4)
   3 shots - 1981 (SP 3)

3a. Working Group of the European Seismological Commission on the Fennoscandian Long-Range Project 1979.

3b. Institute of Geophysics, Polish Academy of Sciences
Institute of Geophysics, Ukrainian Academy of Sciences

5. Geotraverse Baltic See - Black See is about 1500 km long. This profile crosses Yalta seismically active zone, the Crimeun Orogen, south-western part of East European Precambrian Plotform with Ukrainian Shield. The main purposes of there studies are next:
   a) investigation the structure of seismic channels in the lower lithosphere of the East European Plotform,
   b) investigation and comparison the structure of the lithosphere and astenosphere in the aseismic E.E. Plotform and seismically active zone of Yalta,
   c) comparison of a platform structure of lithosphere with structure of the lithosphere of the Blatic Shield. First results of field works 1978 and 1979 were presented in the meeting in Uppsala 1981.

6. Continuation of this project is planned.

7. In preparation.

8. Fig. 8.

Institute of Geophysics, Polish Academy of Sciences

11. Other projects for 1982-1984 (see Figure 5).

a. Deep seismic sounding of the Earth's crust on the LT-7 profile in the Teisseyre-Tornquist zone in North-West Poland (1983):

   Total length of LT-7 profile - 280 km and 5 shot points with distances about 70 km.

b. Continuous reflection profiling in the contact zone between Paleozoic Platform and Teisseyre-Tornquist zone along LT-2 profile (1982):
   Total length of this profile - 55 km.

c. Deep seismic sounding of the Earth's crust on the Carpathian Profile (CP-see Figure 5):
   Total length of CP profile - 320 km 5 shot points are planned.

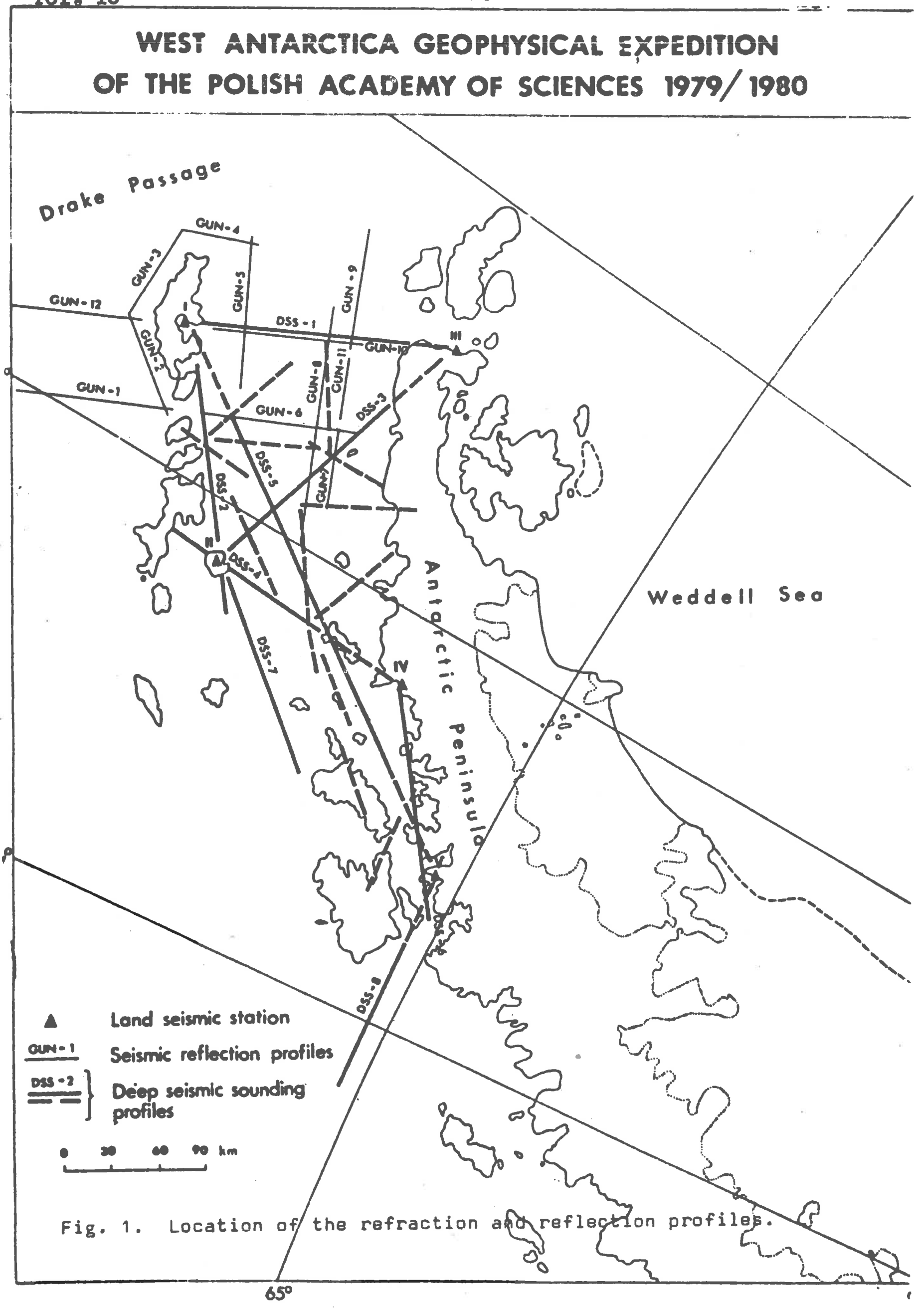


Fig. 1. Location of the refraction and reflection profiles.

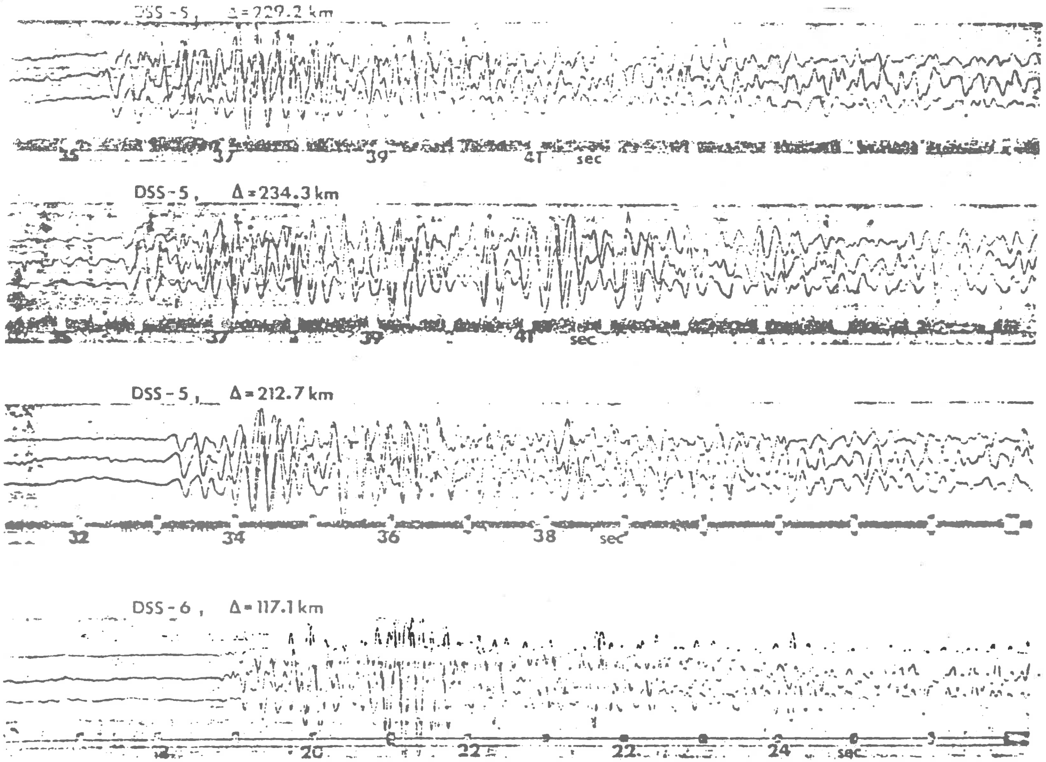


Fig. 2. Examples of the records from deep seismic sounding profiles (vertical components, Δx = 200 m).

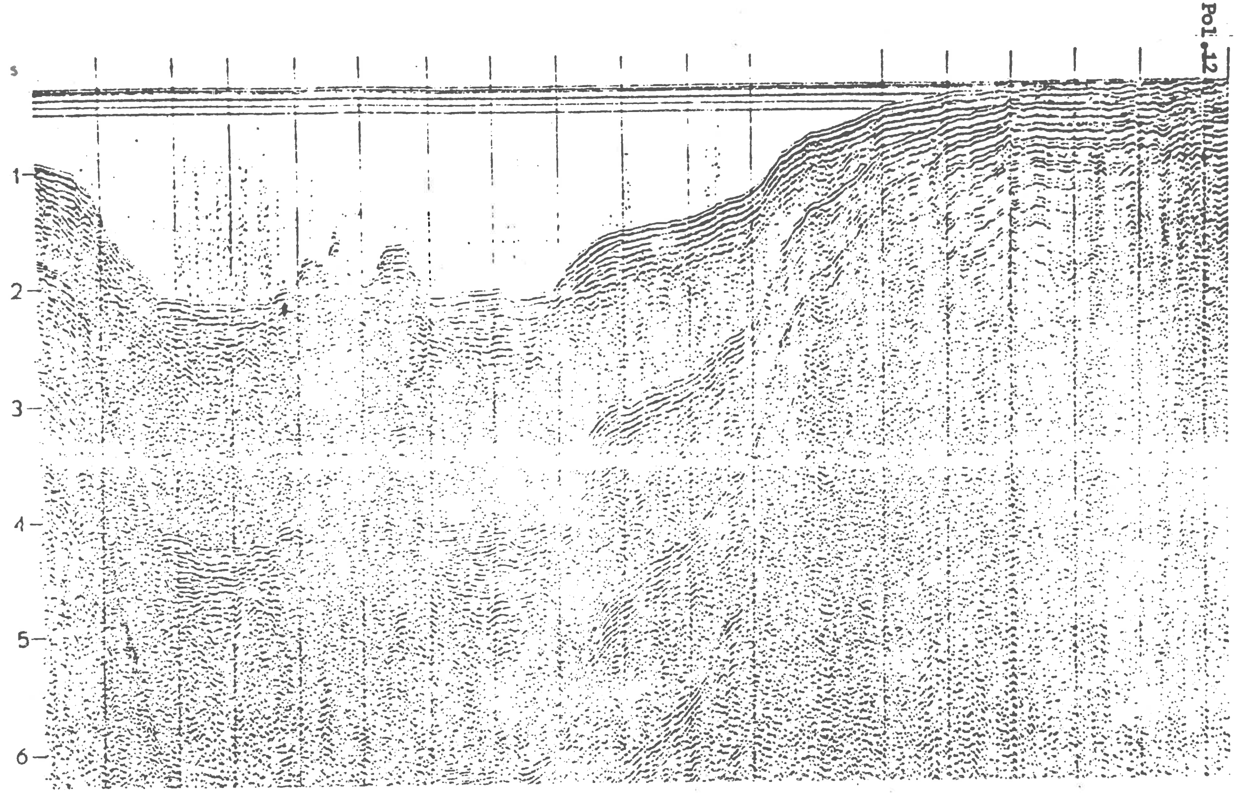


Fig. 3. Seismic reflection profile across the Bransfield Strait (GUN-6, see Fig. 1).

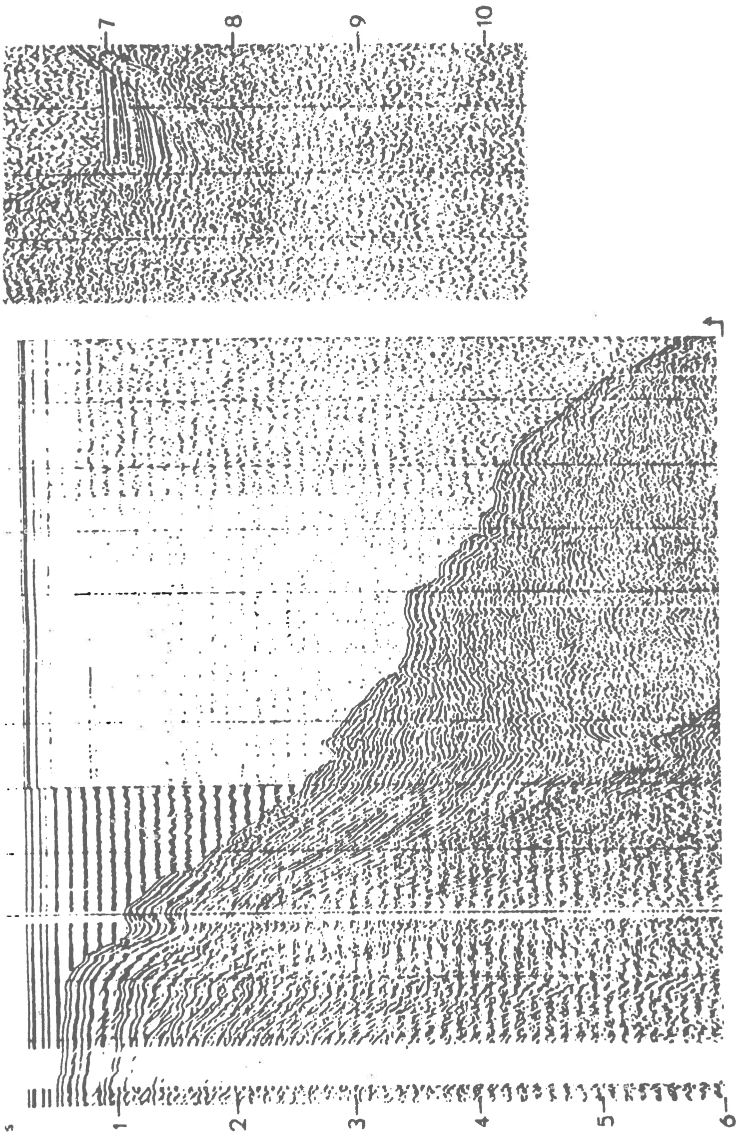


Fig. 4. Seismic reflection profile across the Drake Passage (GUN-12, see Fig. 1).

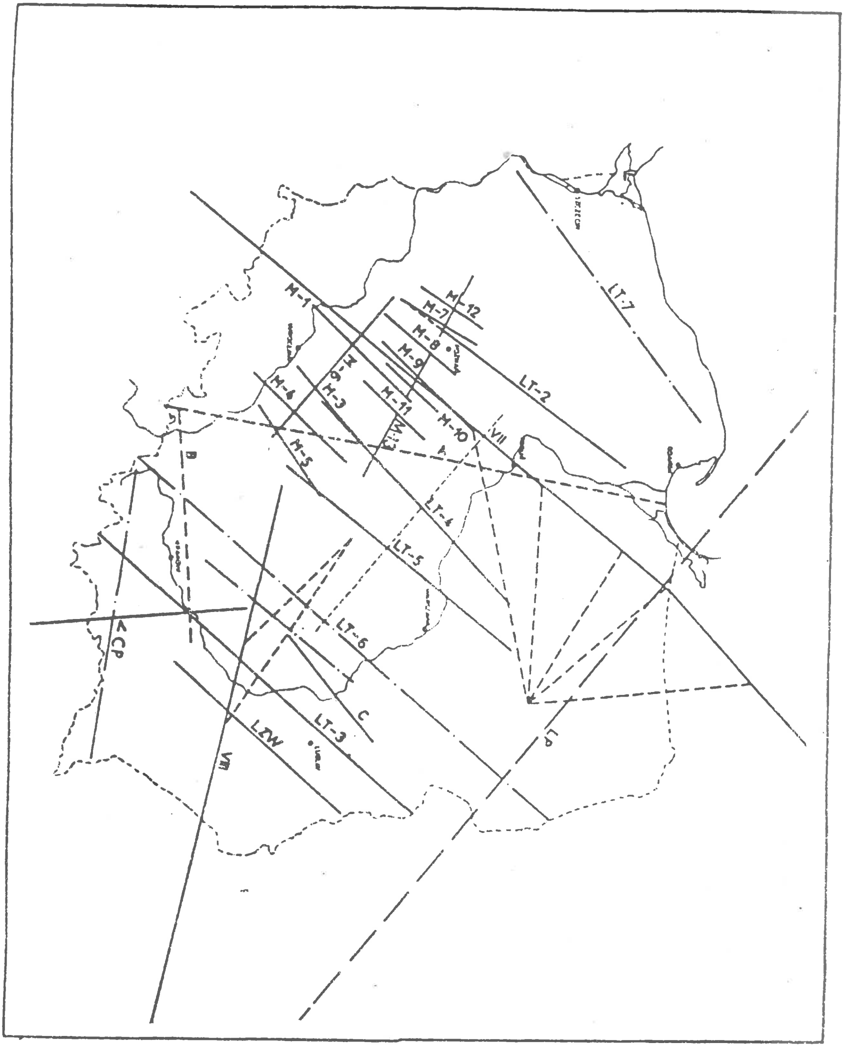


Fig. 5. Location of the DSS profiles on the Polish area.

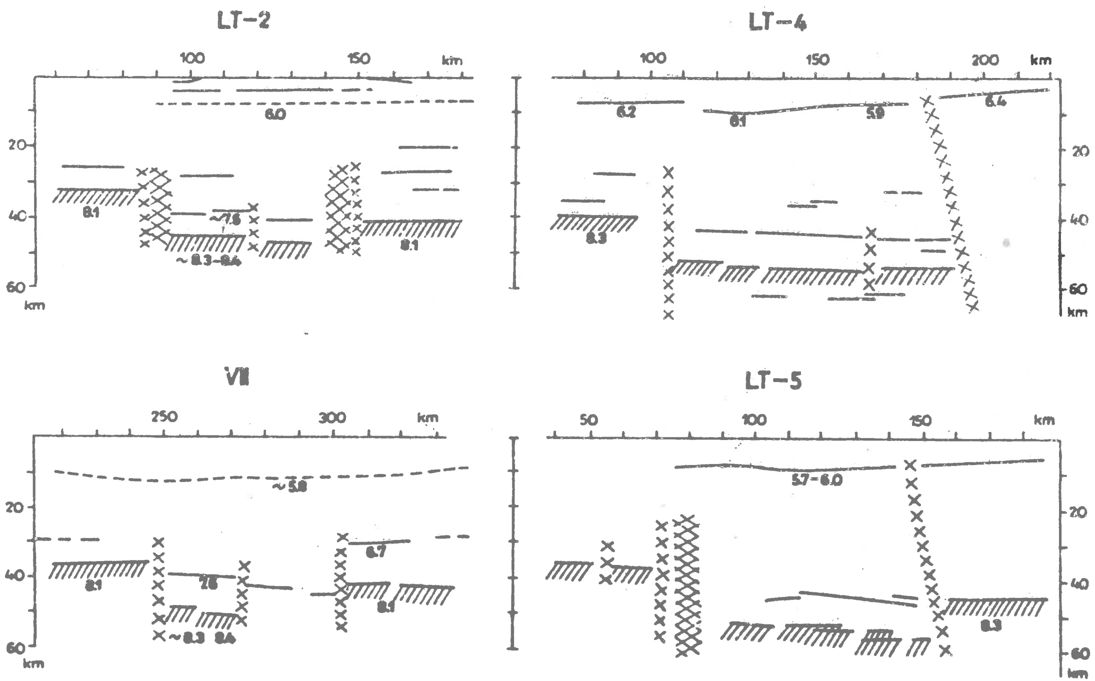


Fig. 6. Examples of the crustal sections from the Teisseyre-Tornquist tectonic zone.

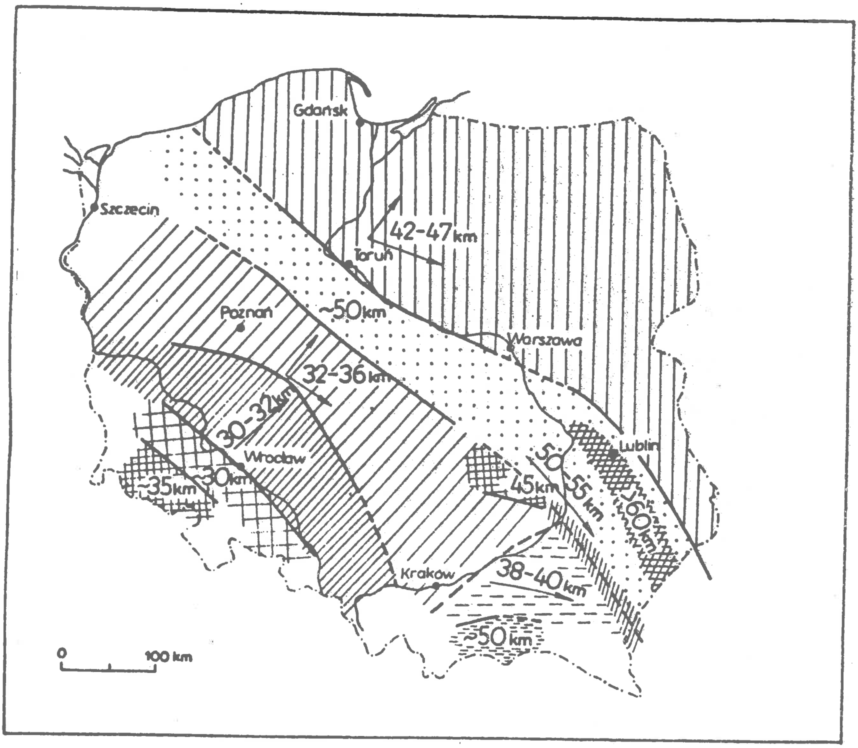


Fig. 7. Scheme of geotectonic division of the Polish area from studies of the Earth's crust by DSS method (42-47: depth of the Moho discontinuity and directions of increase of thickness of the Earth's crust).

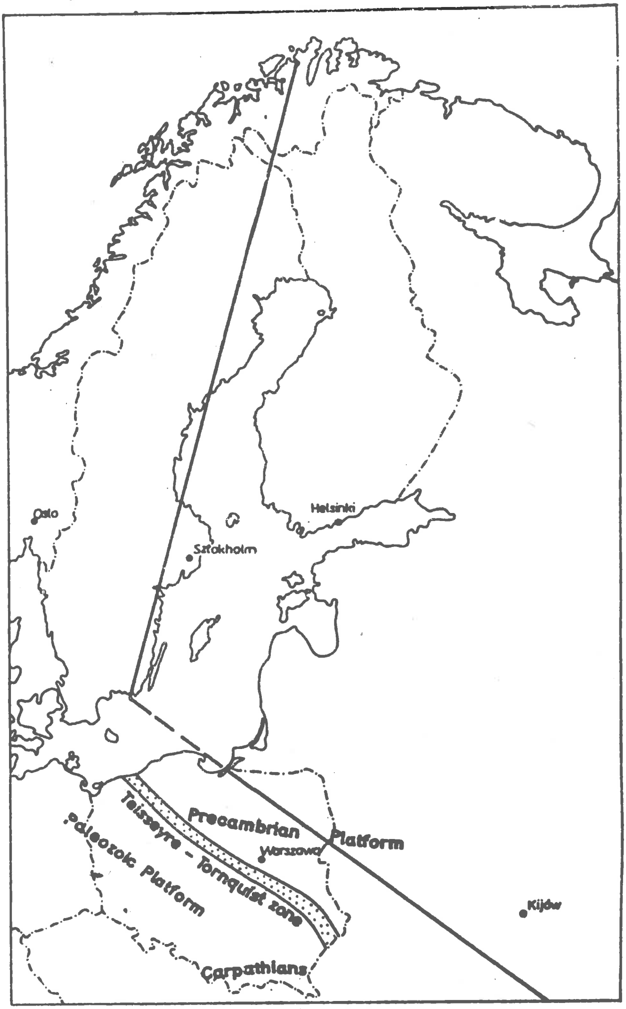


Fig. 8. Location of the Baltic See - Black See Geotraverse.

PORTUGAL (Instituto Nacional de Meteorologia e Geofisica;
L. Mendes Victor).

Name of project: Investigation of the seismotectonics of the territories in Continental Portugal, Azores and Madeira.

Date of field experiments: October 1980
December 1980
May 1981
August 1981
October 1981

Experiments organized by: National Institute of Meteorology and Geophysics

Other participants: October 1980 - Complutense University of Madrid
December 1980 - Geophysical Institute of Lisbon University
Geophysical Center of Lisbon University
May 1981 - Geophysical Institute of Lisbon University
Geophysical Center of Lisbon University
August 1981 - Institut de Physique du Globe de Paris
Geophysical Institute of Lisbon University
Geophysical Center of Lisbon University
October 1981 - Complutense University of Madrid
Geophysical Institute of Lisbon University
Geophysical Center of Lisbon University

Brief description of field experiments:

October 1980

Study of the north-east region of Continent (Morais), 7 shots in 3 shot-points (A, B, C, D, E, F, and G), 3 seismic profiles, one south-north and 2 east-west (see map in annex).

December 1980

(Microzonation of Lisbon) Several radial seismic profiles in the Lisbon region
4 shot-points (PT1, PT2, PT3 and PT4).
(See map in annex).

May 1981

Study of the region of Alqueva dam
14 seismic profiles
19 shots in 5 shot-points (PT1, PT2, PT3, PT4 and PT5)
(See map in annex).

August 1981

Study of the repair between S. Vicente Cape and Gorringe Bank
27 shots in the sea
5 boltom-sea seismographs and 12 stations in land
(See map in annex).

October 1981

Only one seismic profile throw Alentejo, in direction NW-SE.
Shots in the sea near Cadiz.

Summary of the main results so far available

The seismic probing demonstrates the absence of a root towards the lower crust and favours a mechanism of thrust and nappe emplacement.

Publications

High to low velocity sucession in the upper crust related to tectonic emplacement: Trás-os-Montes - Galicia (Iberia), Brittany and Limousin (France)

- Alfred HIRN; Luísa SENOS; M. SAPIN; Luiz MENDES VICTOR (to be published in the Geophysical Journal of the Royal Astronomical Society).

Position map with shot points

(See annexes).

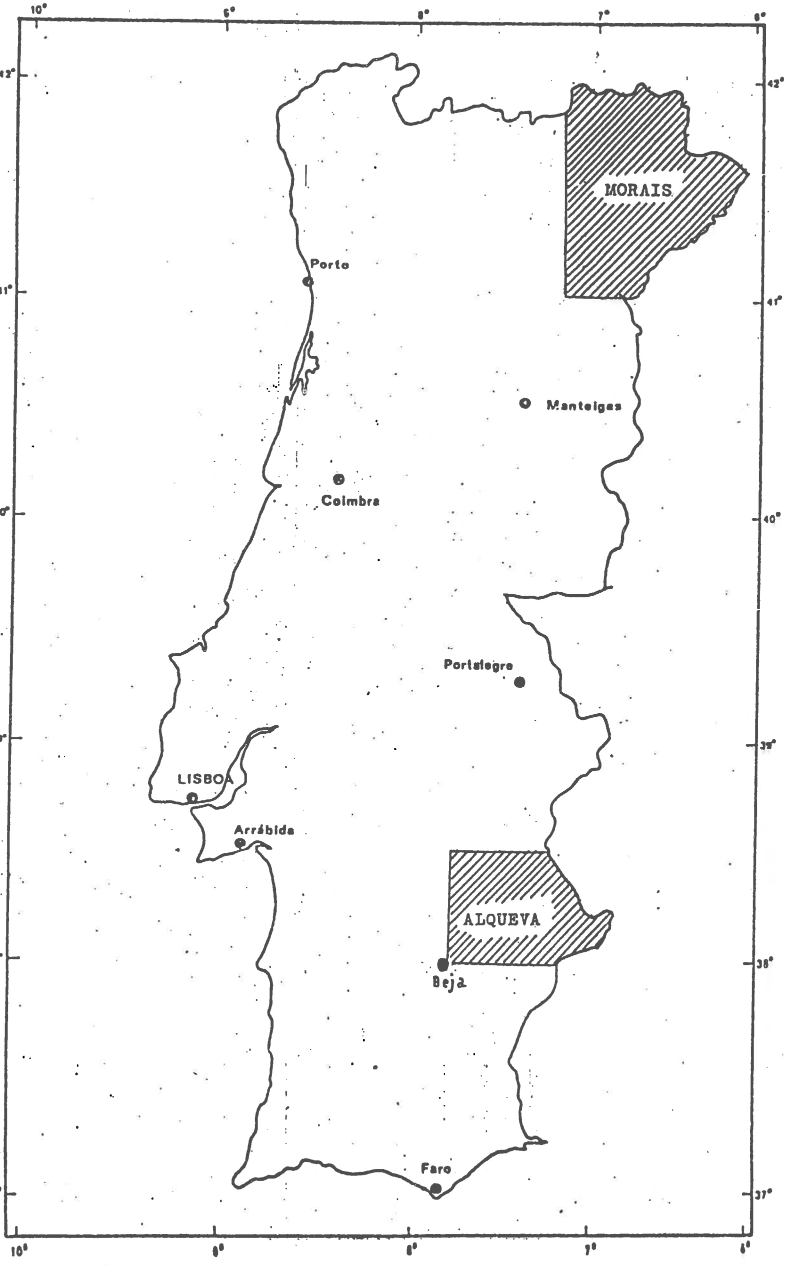
Examples of record section

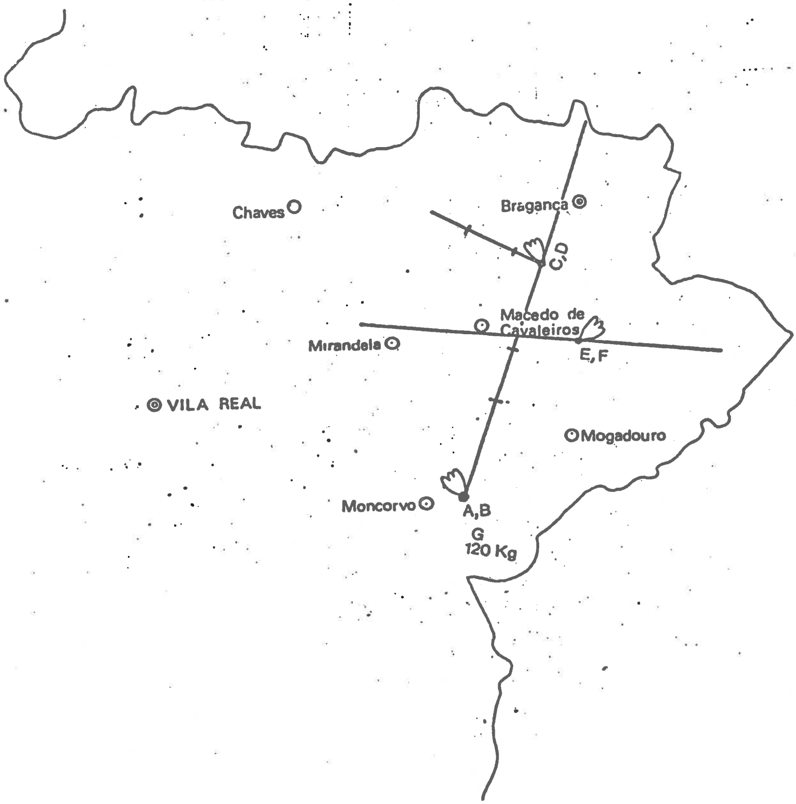
(See annex).

Do you plan other projects for 1983 and 1984 ?

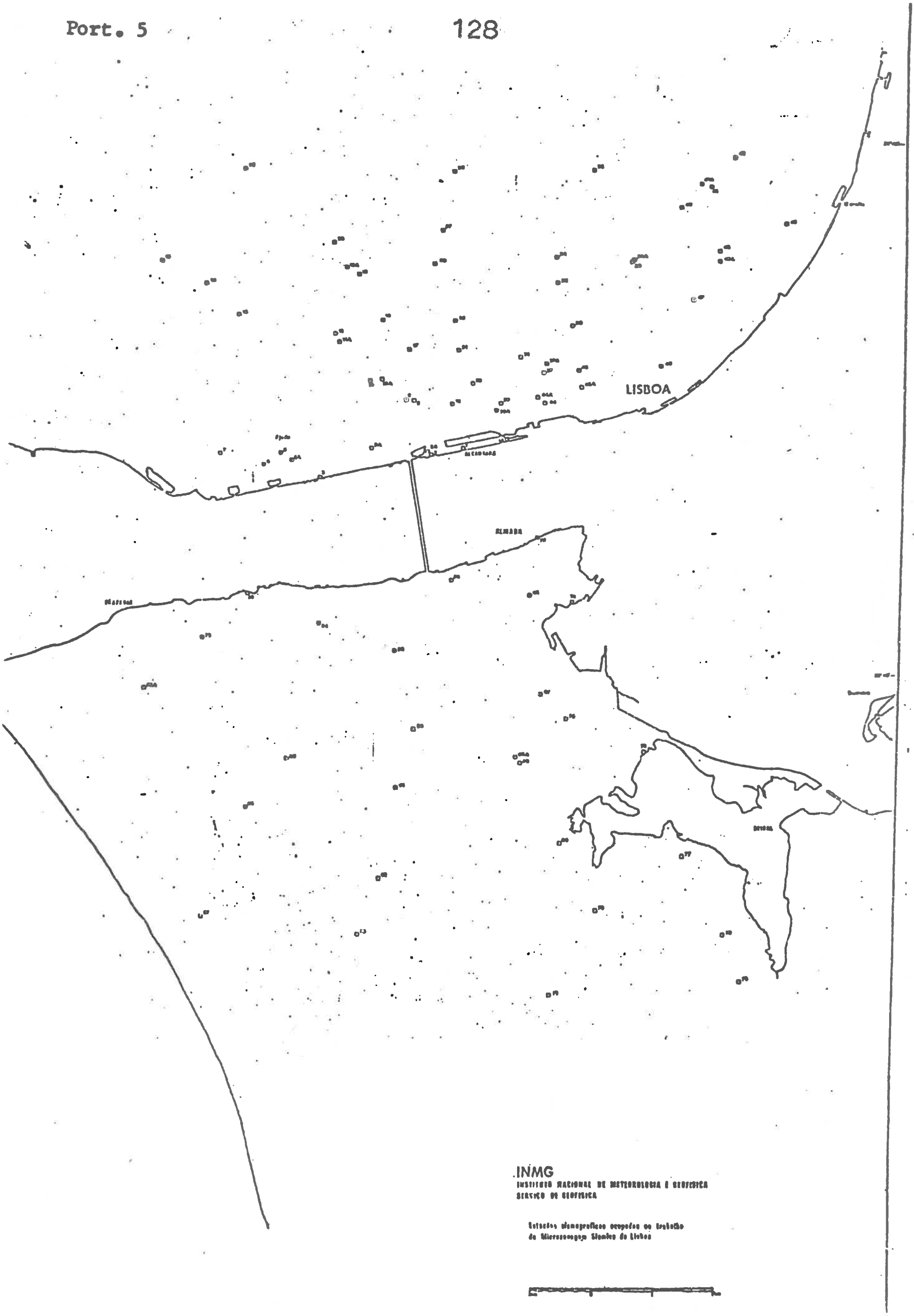
Study of central part of Continent.

Study of west islands in Azores.

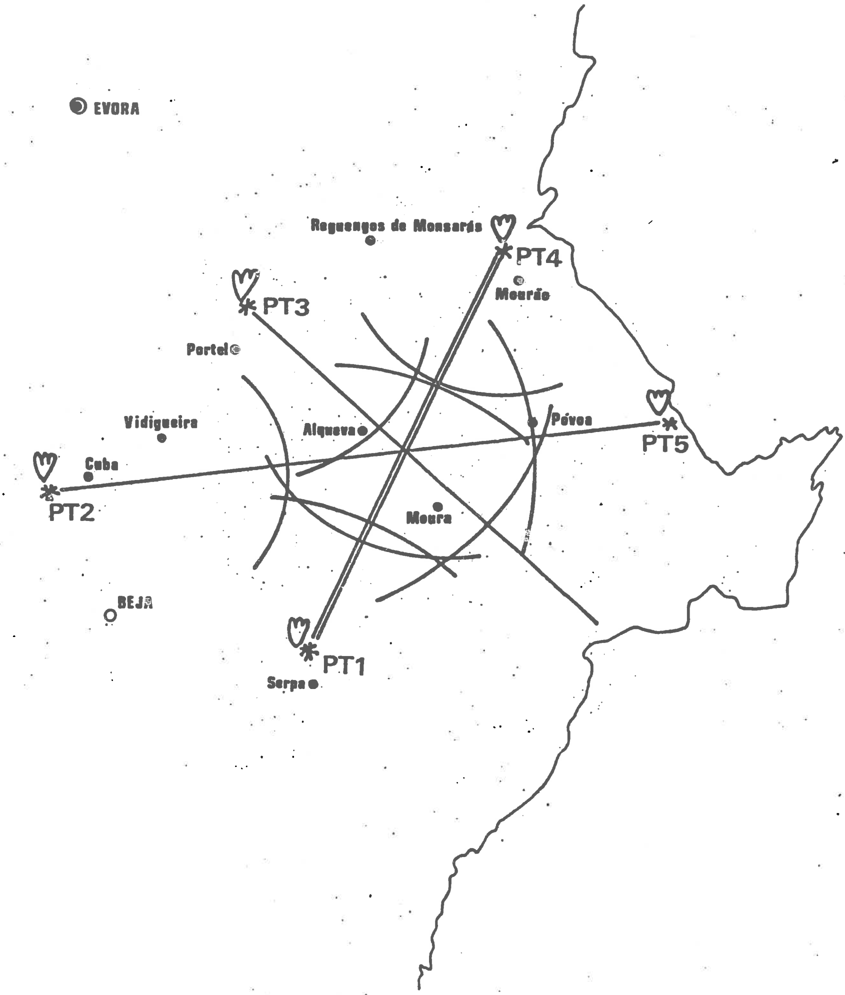

MORAIS
Porto
Manteigas
Coimbra
Portalegre
LISBOA
Arrábida
ALQUEVA
Beja
Faro



TRÁS OS MONTES
(M O R A I S)


LISBOA
INMG

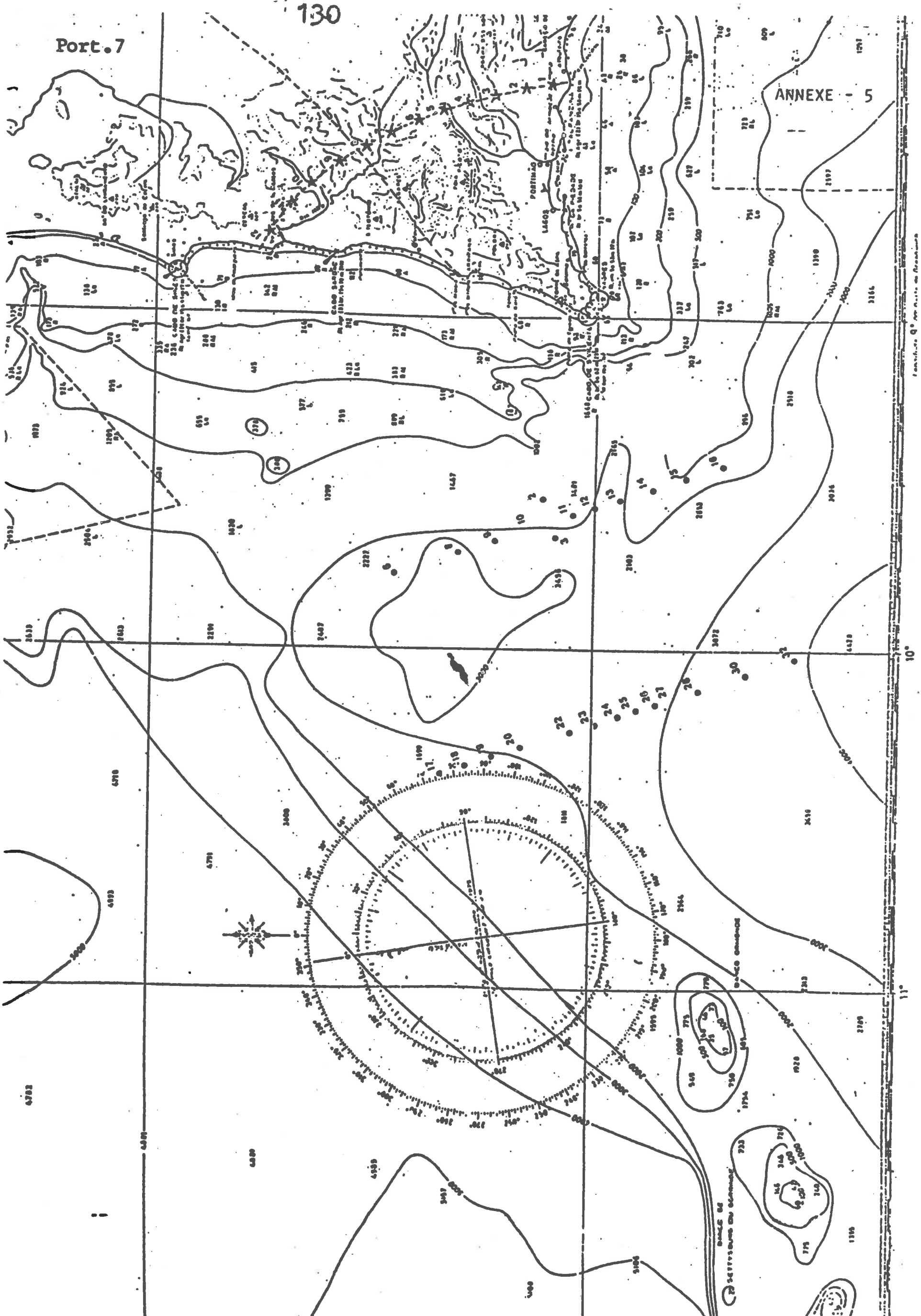
Port. 6



ALQUEVA

Port.7

ANNEXE - 5



SPAIN (Catedra de Geofisica, Facultad de Ciencias Fisicas, Universidad de Madrid; A. Udias)

A. 1.- Name of proyect

Campaña de Perfiles Sísmicos Profundos en el Golfo de Cádiz y Sistema Ibérico.

2.- Date

7 Oct. 1981 - 5 Nov. 1981.

3.- Organizers and participants

- Grupo de Trabajo de Perfiles Sísmicos Profundos. Cátedra de Geofísica. Universidad Complutense, Madrid.
- Departamento Física de la Tierra y del Cosmos. Universidad de Barcelona.
- Instituto Geográfico Nacional (IGN).
- Instituto y Observatorio de la Marina (IOM).
- Instituto de Geología del Consejo Superior de Investigaciones Científicas (CSIC).
- Institute of Geophysics. ETH Hönggerberg CH-8093 Zurich.
- Armada Española.

4.- Description of field experiment in 1981

The experiment was divided in 3 parts:

a) Gulf of Cádiz. Marine profile and land profiles.
b) Ronda.
c) Iberic System.

Number of stations: 26. Number of explosions: 25.
All explosions at sea by the Hidrographic Ship of the Spanish Navy "Malaspina".

Part (a). 14 shots at sea with charges between 100 and 400 kg TNT. Total length 169 km, and interval between shots: 13 km. Recorded at both ends of the line by station on land.

6 of the large explosions were recorded along 4 lines in land of approximate 80 km; each one perpendicular to the coast.

Part (b). To study the ultramaffic material at Ronda two shot profiles were performed in the area with 26 stations along 80 km lines.

The position of the lines and explosions for part (a) and (b) is shown in figure 1.

Part (c). Shots at sea were recorded along a line of 180 km that follows the trend of the Iberic System. Explosion ranges from 14 kg to 200 kg. A second line was observed from the coast to 80 km at an angle of the first one. Position of the lines and explosions is shown in figure 2.

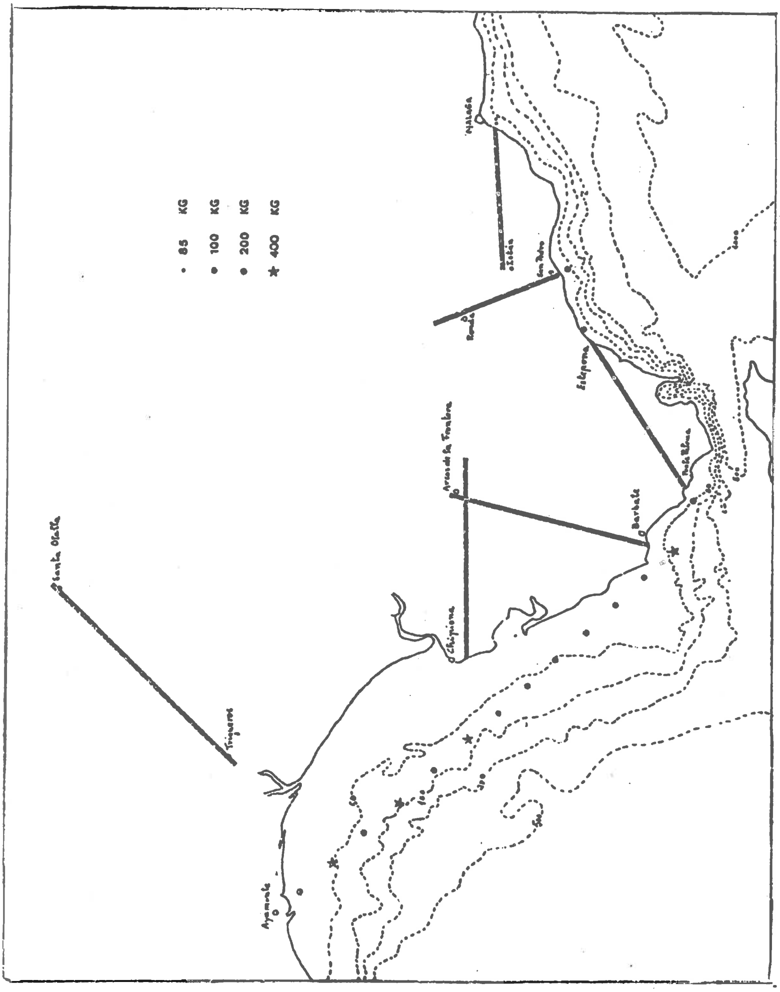


FIG-I

Sp.3

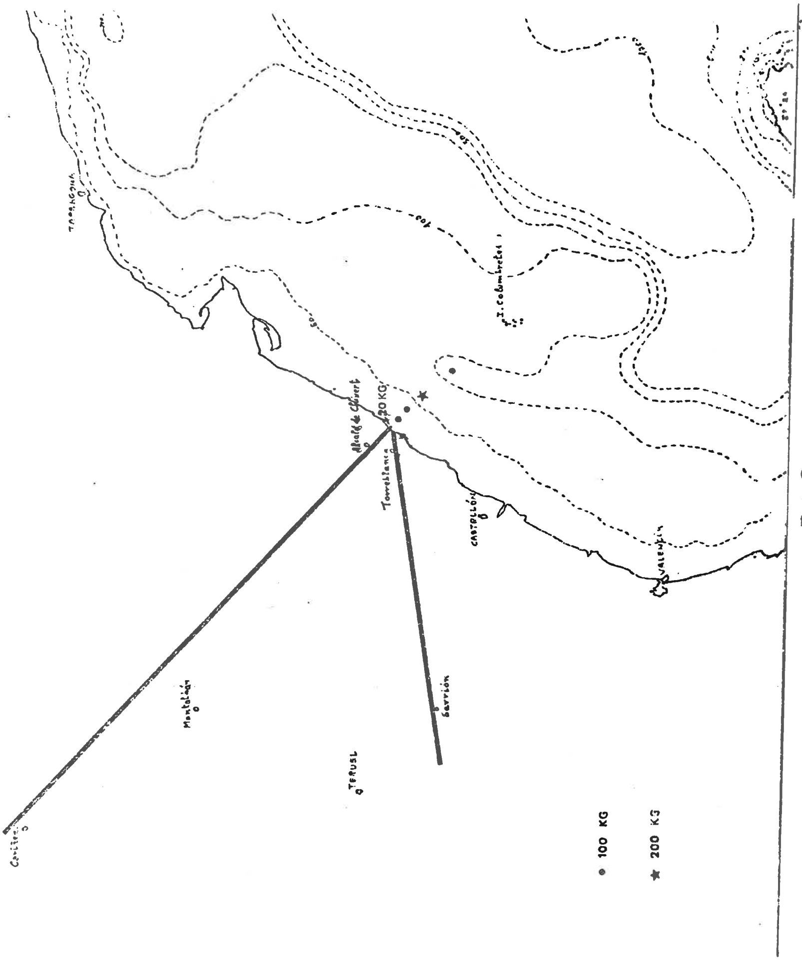

TARRAGONA
I. Columbretes
Alcalá de Chivert
Torreblanca
CASTELLÓN
VALENCIA
Montalbán
TERUEL
Sarrión
100
50
• 100 KG
★ 200 KG

FIG - II

B. 1 Structure of the Crust and Upper Mantle beneath the Balearic Islands (Western Mediterranean).

. 2 1976

. 3 E. Banda, J. Ansorge, M. Boloix and D. Cordoba.
Catedra de Geofisica Universidad Complutense, Madrid 3 (Spain).
Institute of Geophysics, ETH-Hönggerberg, CH-8093 Zürich (Switzerland).
Instituto y Observatorio de Marina, San Fernando, Cadiz (Spain).

. 4 DSS were conducted along the Balearic promontory by Spanish, Swiss and French institutions in 1976. Ten depth-charges, ranging in size from 143 to 1010 kg fired at sea by the Spanish Navy were used as sources for seismic refraction measurements along the Balearic chain. The shooting ship steamed southwesterly from north of Menorca towards the Iberian peninsula while explosives were deposited on the sea floor and detonated at optimum depth with the exception of B7 which was a suspended charge and detonated 740 m above the sea floor. Twenty-four stations, 4-5 km apart, were installed on the islands.

. 5 A sedimentary cover of 4 km around Ibiza to 7 km under Mallorca overlies the crystalline basement. This basement with a P-wave velocity of 6.0 km/s at the top reaches a depth of at least 15 km under Ibiza and 17 km under Mallorca with an increase to 6.1 km/s at these depths. The crust-mantle boundary lies at a depth of 20 km and 25 km, respectively. A well documented upper-mantle velocity of 7.7 km/s is found along the entire profile. The Moho rises to a depth of 20 km about 30 km north of Mallorca and probably continues rising towards the center of the North Balearic Sea. The newly deduced crustal structure together with previously determined velocity-depth section in the North Balearic Sea as well as heat flow and aeromagnetic data can be interpreted as an extended rift structure caused by large-scale tensional processes in the Upper Mantle. The available data suggest that the entire zone from the eastern Alboran Sea to the area north of the Balearic Islands represents the southeastern flank of this rift system. In this model the provinces of Spain along the east coast would represent the northwestern rift flank.

.6 -

.7 E. Banda, J. Ansorge, M. Boloix and D. Cordoba, 1980: "Structure of the Crust and Upper Mantle beneath the Balearic Islands (Western Mediterranean". Earth and Planetary Science Letters, 49 219-230.

.8 Fig. 1

.9 Fig. 3 - 8.

.10 Fig. 11

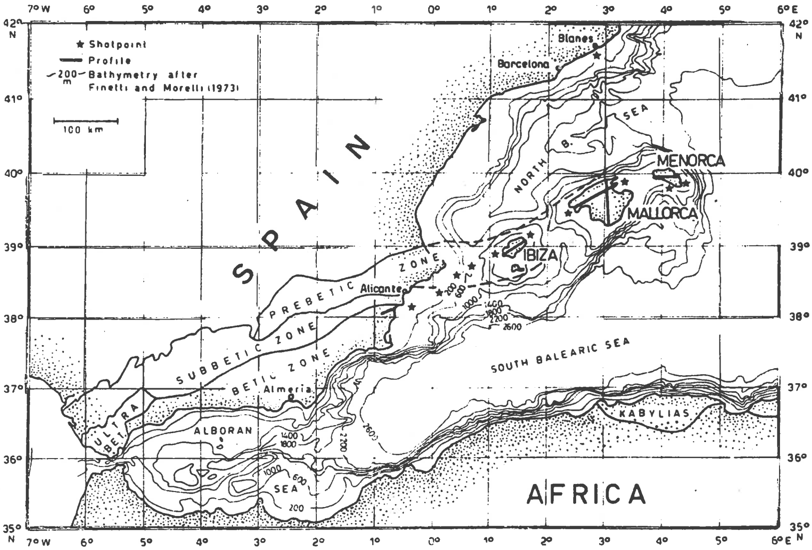


Fig. 1. Bathymetric map [17]. Shotpoint positions (stars) and recording lines are indicated. Shotpoints are numbered B1 to B10 from NE to SW.

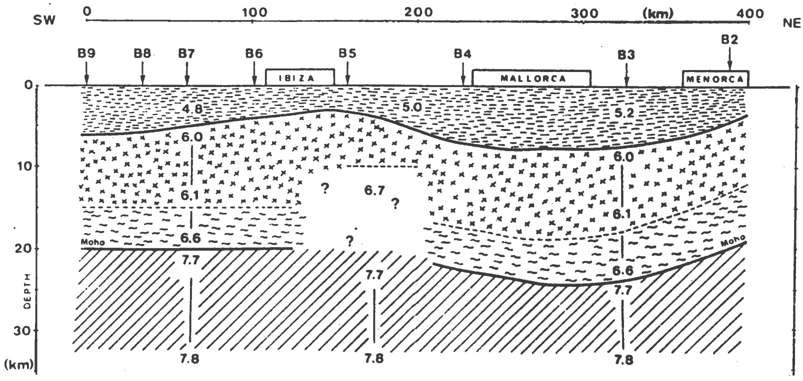


Fig. 11. Model of the crust and upper mantle along the strike of the Balearic Islands (numbers give P-wave velocity in km/s).

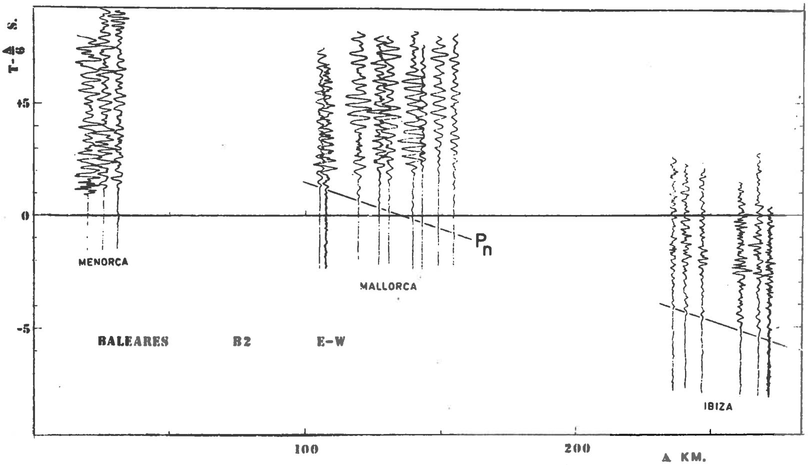


Fig. 3. Record section for shot B2 with P_n correlation.

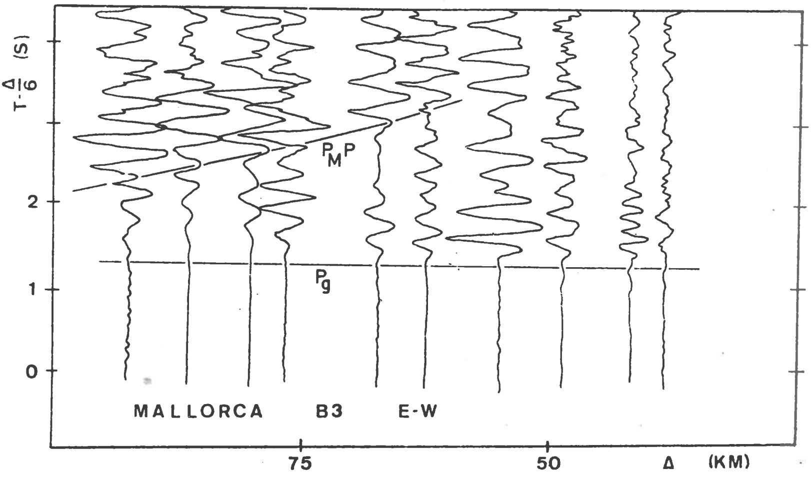


Fig. 4. Record section for shot B3, recorded on Mallorca. P_g and P_MP correlations are indicated.

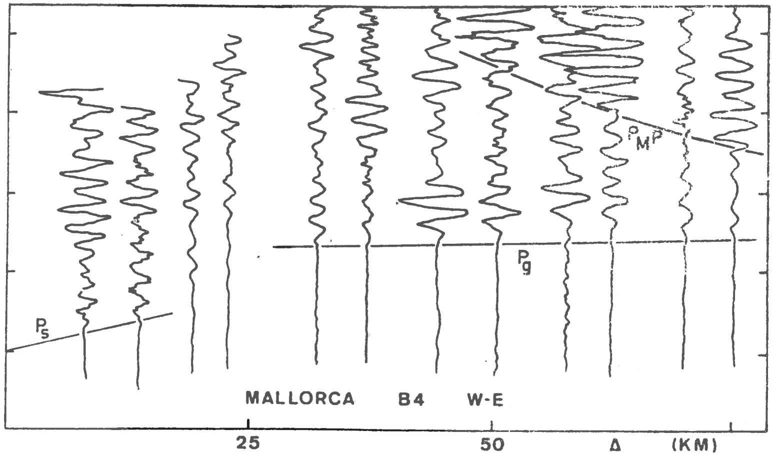


Fig. 5. Record section for shot B4, recorded on Mallorca with P_s, P_g and P_MP correlations.

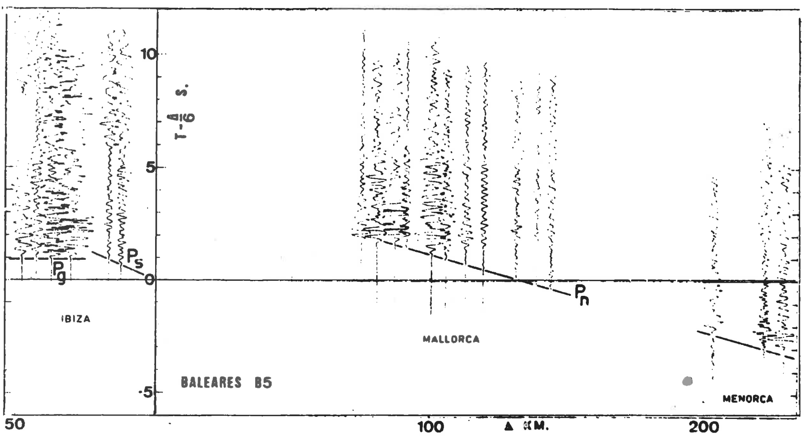


Fig. 6. Record section for shot B5 with P_s, P_g and P_n correlations.

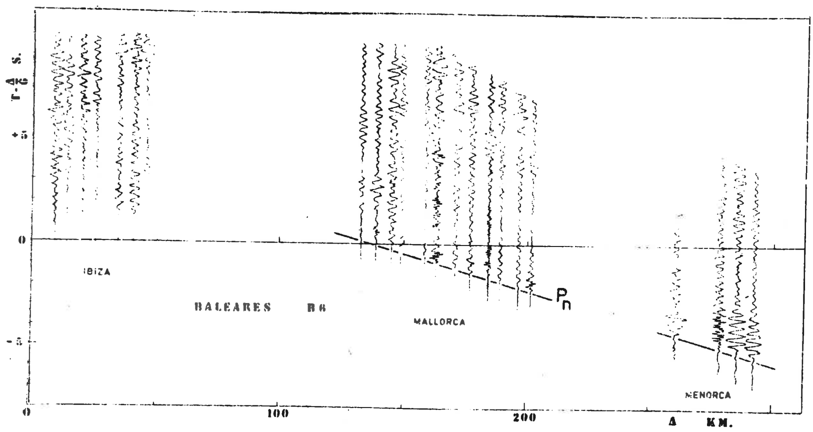


Fig. 7. Record section for shot B6 with P_n correlation.

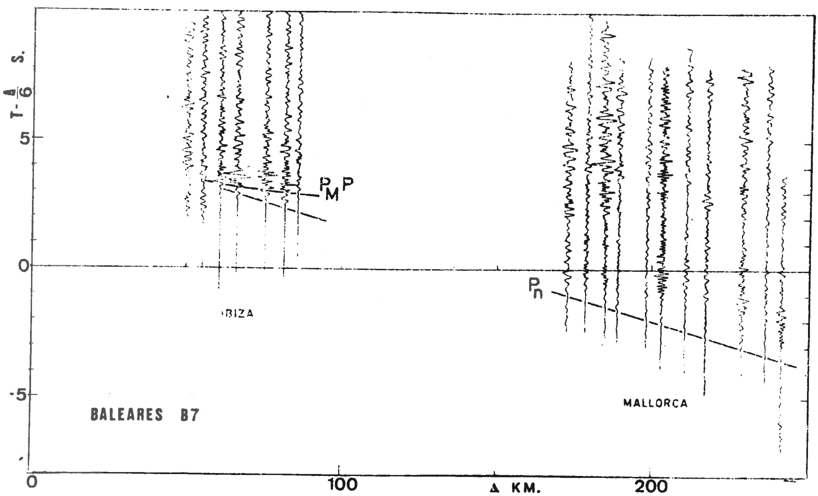


Fig. 8. Record section for shot B7 with P_MP and P_n correlations.

SWITZERLAND (Institut für Geophysik, ETH, Zürich; Dr. J. Ansorge)

1 9 8 0
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1) Yellowstone - Snake River Plain Seismic Refraction Experiment II

2) 28 June - 26 July 1980

3a) Department of Geology and Geophysics, University of Utah, Salt Lake City, USA (R.B. Smith).
Department of Geosciences, Purdue University, West-Lafayette, USA (L.W. Braile).
Institute of Geophysics, ETH Zürich, Switzerland (J. Ansorge).
Geophysical Institute, University of Karlsruhe, Germany (C. Prodehl).

3b) --

4) 23 explosions from boreholes were recorded by 46 recording stations on 6 profiles and arrays in the Snake River Plain, the Yellowstone Park, and across the boundaries of these areas into the undisturbed Paleozoic surrounding regions of Idaho and Montana.

5) Not yet available

6) No specific plans

7) Results of experimental phase I (1978) are published in a compilatory issue of Journal of Geophysical Research, 87, 2581-2766, 1982.

8) See enclosed Figure

9) --

10) --

11) --

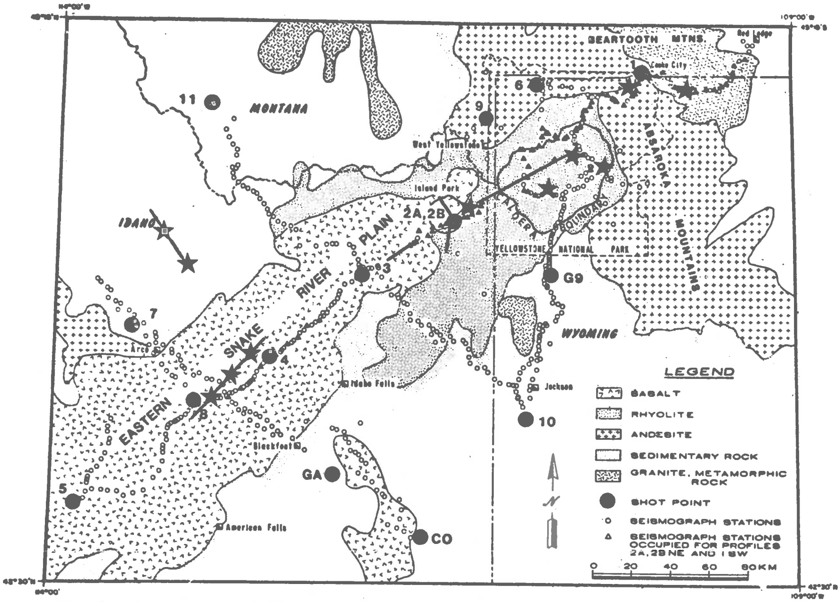


Fig. 1. Index map for 1978 Yellowstone-eastern Snake River Plain seismic experiment. Shot points are indicated by solid circles; station locations correspond to solid triangles for sites occupied on profiles 1SW and 2A2BNE. Open circles correspond to sites occupied for other profiles [see Braile et al., this issue; Schilly et al., this issue; Lehman et al., this issue; Sparlin et al., this issue].

* , — . Location of shotpoints and profiles for the 1980 Snake River Plain Project togethern with those of 1978.

In the Yellostone Park the stations were set up as an array.

One additional N - S profile crossed the northern boundary of the Snake River Plain just west of the given frame.

1 9 8 1 I
===========

1) Crustal Structure under the Western Betics (Southern Spain) and under the Iberic System (Central and Eastern Spain).

2) 6. - 20. October 1981

3a) Universidad Complutense de Madrid
Instituto y Observatorio de la Marina, San Fernando, Cadiz
Instituto Geografico Nacional, Madrid
Universidad de Barcelona
Consejo Superior de Investigaciones Cientificas
Instituto Geologico y Minero, Madrid
Institute of Geophysics, ETH Zürich

3b) --

4) 26 field stations recorded 23 explosions in the Golf of Cadiz, along the Costa del Sol and offshore north of Valencia on 8 profiles. Charges ranged from 85 kg to 400 kg.

5) --

6) --

7) --

8) See enclosed Figures.

9) --

10) --

11) --

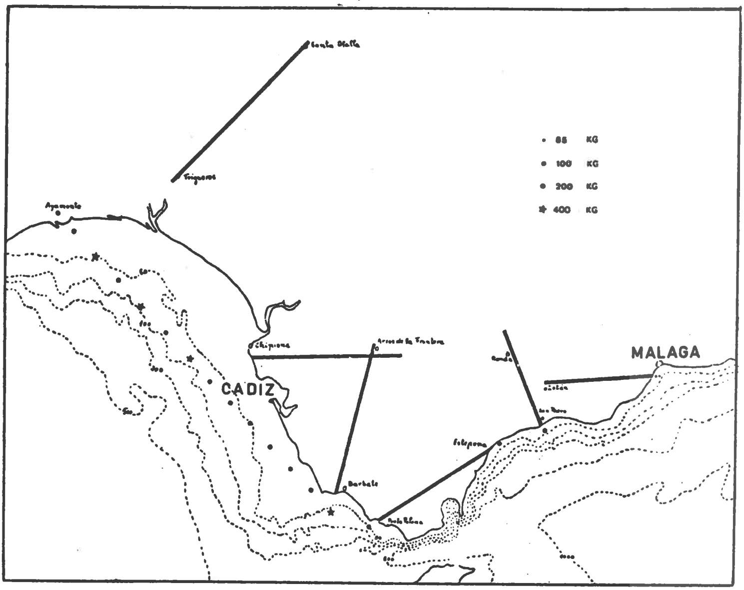


Fig. 1 : Location of shotpoints and profiles in the Western Betic Cordillera and the Golf of Cadiz

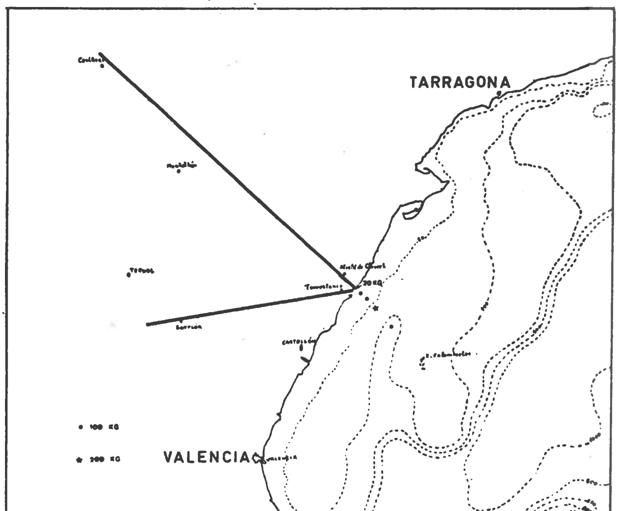


Fig. 2 : Location of shotpoints and profiles in the Iberic System north of Valencia

1 9 8 1 II

1) Regional survey of the upper crustal structure in the Southern Black Forest (Germany) and the Eastern part of the Swiss Jura (Switzerland).

2) 19. - 21. May 1981 and 15. - 18. September 1981

3a) Institute of Geophysics, ETH Zürich

3b) Geophysikalisches Institut, University Karlsruhe
Institut für Geophysik, Technical University Clausthal
Institut für Allgemeine und Angewandte Geophysik, University München
Geowissenschaftliches Observatorium Schiltach
Institut für Meteorologie und Geophysik, University Frankfurt
Prakla-Seismos GmbH, Hannover

4) Part I (May 1981):

46 field stations recorded 4 quarry blasts of 500 kg each on six profiles radiating from the shotpoint to a distance of up to 47 km. Mean station spacing 1 km.

Part II (September 1981):

46 field stations recorded 9 shots from boreholes with charges from 100 to 600 kg along a NNW - SSE profile over a distance of 65 km. Mean station spacing 0.6 km.

Prakla-Seismos, Hannover, recorded these shots on three spreads on the same profile of 10 km length each.

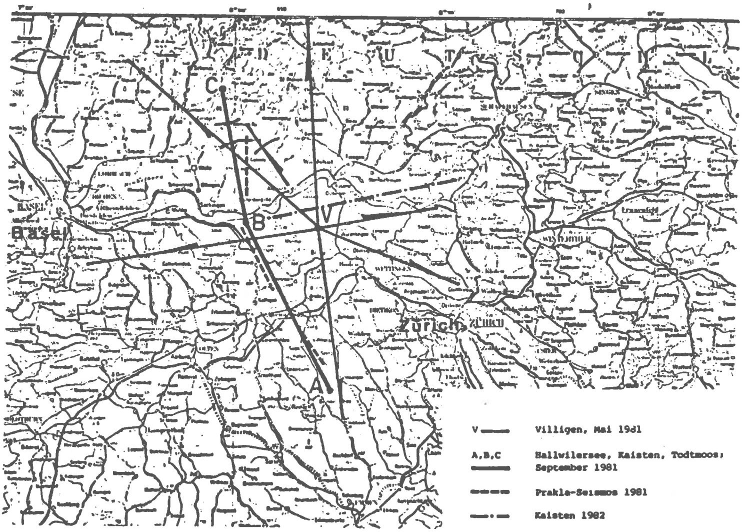
5) Interpretation is not yet completed.

6) A supplementary refraction experiment was performed in 1982 along an E - W profile in the same area.

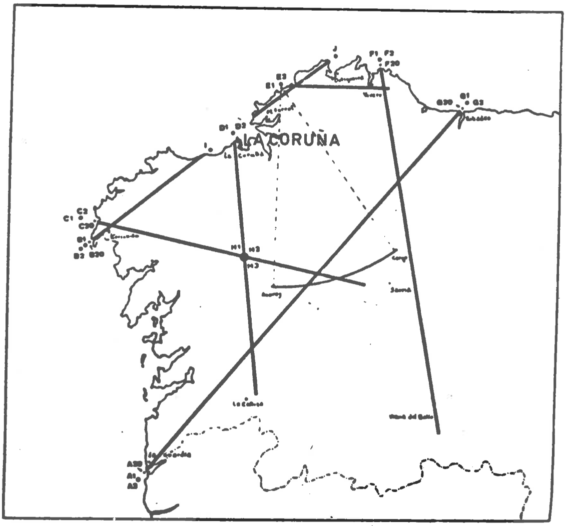
7) --

8) See enclosed Figure

9) - 11) --



Location of shotpoints and profiles in the Southern Black Forest and the Swiss Jura



Location of shotpoints and profiles in Galicia, North-western Spain.

1 9 8 2 I

===========

1) Supplementary refraction survey in the northern part of the Swiss Jura.

2) 4 - 5 May 1982

3a) Institute of Geophysics, ETH Zurich

3b) Geowissenschaftliches Observatorium Schiltach

4) 19 field stations recorded 2 shots from boreholes along a E - W profile in the same region of the 1981 survey.

5) --

6) --

7) --

8) See Figure of 1981 II

9) --

10) --

11) --

1 9 8 2 II
===========

1) Crustal structure under Galicia, Northwestern Spain

2) 7 - 23 July 1982

3a) Universidad Complutense de Madrid
Instituto y Observatorio de la Marina, San Fernando, Cadiz
Instituto Geografico Nacional, Madrid
Universidad de Barcelona
Consejo Superior de Investigaciones Cientificas
Instituto Geologico y Minero, Madrid
Institute of Geophysics, ETH Zurich

3b) --

4) 33 field stations recorded 21 explosions offshore at sea and 3 quarry blasts. Six profiles were occupied which reach a maximum distance of 180 km.

5) --

6) --

7) --

8) See Figure

9) --

10) --

11) --

UNITED KINGDOM (Geol. Dept., Chelsea College, London; D. J. Blundell)

DEEP SEISMIC SOUNDING

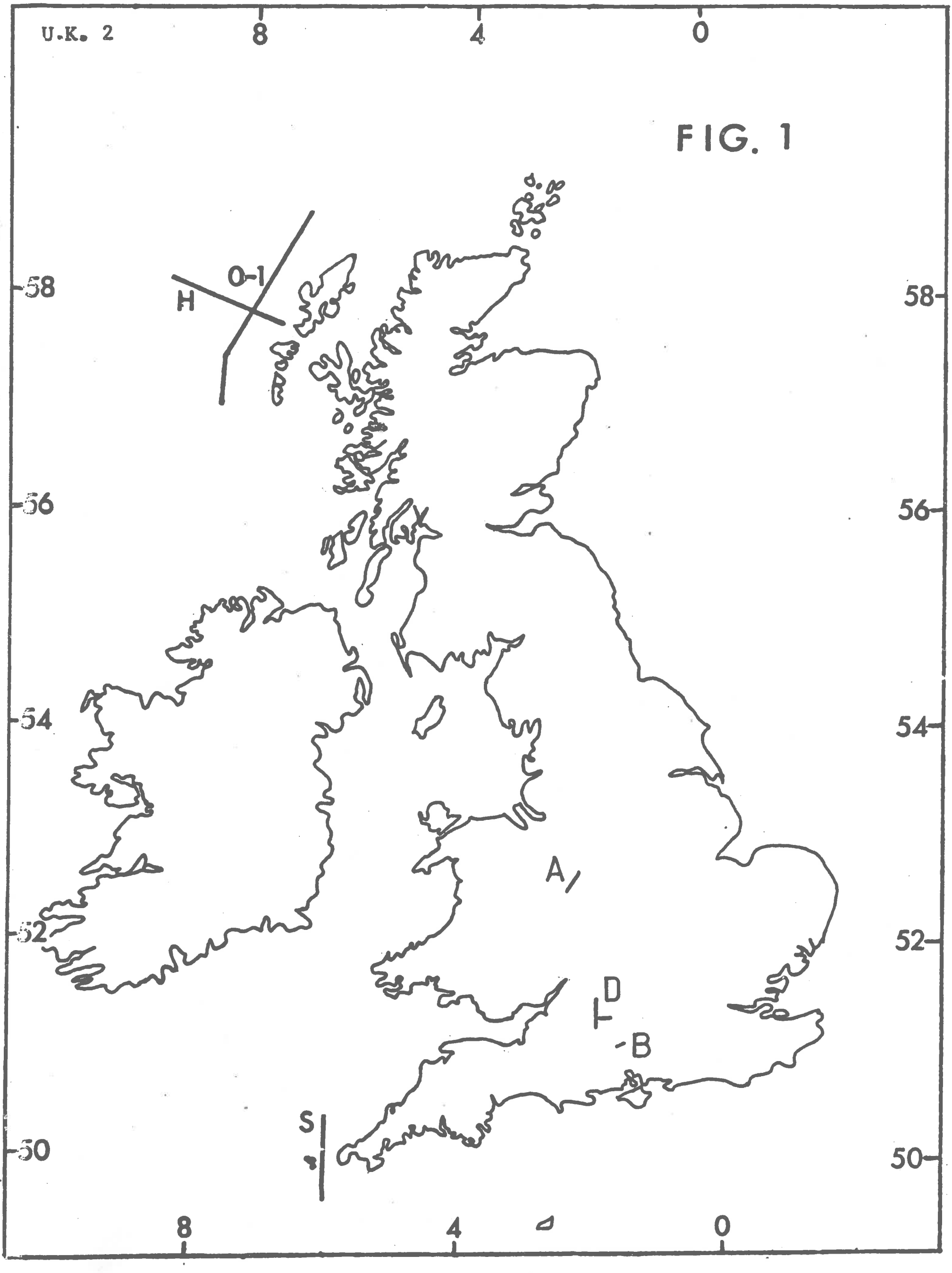
A.1 Feasibility study for deep seismic reflection profiling in UK.
.2 Analysis of records 1980-82.
.3a D. Blundell, Chelsea College, University of London.
.b R. McQuillin, D. Smythe, N. Kenolty, R.A. Chadwick, Institute of Geological Sciences.
D. Matthews, University of Cambridge.
G. Robson, M. Bacon, Shell UK Exploration and Production.

4-5 The study began with a review of existing available offshore seismic reflection records in areas where basement is shallow. Part of a regional survey (Fig.1, H and O-1) made by Geophysical Surveys International in 1972 west of the Hebrides was reprocessed on a test basis to find optimum parameters for later work and to enhance basement features. A line crossing a granite body near the Scilly Isles (Fig.1, S) was also processed and interpreted. Short lines on land in Shropshire and Hampshire (Fig.1 A and B) fired by Shell UK Exploration and Production were recorded to 15 sec TWT. Although the former showed no basement reflections, the latter displayed shallow dipping reflections between 7 and 9 seconds TWT. Two intersecting reflection profiles near Devizes (Fig.1, D) were recorded for the Institute of Geological Sciences with TWT to 12 seconds. These have been interpreted as showing intra-basement reflections and the presence of a thrust associated with the Variscan Deformation Front. On the basis of these observations and an analysis of the value of deep seismic reflection surveys made in other countries, a case was prepared to seek funding for a national UK research programme of deep seismic reflection profiles. From this has evolved the British Institutions Reflection Profiling Syndicate which has obtained substantial funding from the Natural Environment Research Council and has been established since 1981 under the direction of Dr. D.H. Matthews at University of Cambridge.

6. The project now continues as BIRPS.

7. Blundell, D.J., 1981. The nature of the continental crust beneath Britain <u>in</u> Illing, L.V. and Hobson, G.D. (eds.). Petroleum geology of the continental shelf of NW Europe p.58-64.
Kenolty, N., Chadwick, R.A., Blundell, D.J. and Bacon, M., 1981. Deep seismic reflection survey across the Variscan Front of southern England. Nature, v.293, p.451-453.

8. Fig.1 shows positions of survey lines.


U.K. 2
8
4
0
FIG. 1
58
58
0-1
H
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54
A
52
52
D
B
S
50
50
8
4
0

British Institutions Reflection Profiling Syndicate; BIRPS

B.1 MOIST (Moine and Outer Isles Thrusts seismic profile).

2 23-25 March 1981.

3a British Institutions Reflection Profiling Syndicate (BIRPS)
A Dobinson, R McQuillin, D K Smythe, Institute of Geological Sciences, Edinburgh.
D Blundell, Chelsea College, London.
D Matthews, University of Cambridge.

3b

4 The survey consisted of one line running from the Pentland Firth to 30km NW of the Butt of Lewis offshore the northern coast of mainland Scotland, a total of 181km. The survey was conducted by Western Geophysical Co of America who also processed the data to specifications and using parameters defined by the BIRPS research group.

A conventional reflection seismic acquisition system was used, the source and receiver configuration being such as to optimise detection of deep (low frequency) reflections.

The energy source was a 16 gun tuned airgun array of 905 cu.in. capacity operating at 4500 psi towed at a depth of 12m. Coverage: 30 fold. Shot interval 50m. The receiving array consisted of a 3km cable which was configured as 60 sections of 50m groups and 50m group interval towed at a depth of 15 ± 2m. Sixty channels of data were recorded on a DSF V system, IFP in SEGB Format at 1600 bpi. Records were obtained to 15 seconds TWT with a 4msec sample rate.

Data were processed using a receiver array simulation; 3 group mix weighted 1·1·1 and source array simulation; 5 shot mix weighted 1·2·2·2·1. Deconvolution was applied before and after stack, the stack being 30 fold NMO with far trace mute, 25m CDP interval.

5 The aim of the project was to investigate crustal structure down to the Moho and in particular the geometry of major Caledonian thrusts, including the Moine and Outer Isles Thrusts. This objective was fully accomplished. The Moho discontinuity is a strong reflector at about 27km depth detected along the entire length of the profile. Major thrust planes are mapped in crystalline basement down to the lower crust. In the western end of the profile, a suite of reflectors dips from mid-crustal depths in an easterly direction intersecting the Moho and continuing to a depth of about 40-45km (see 10 below).

6 This project will be continued in 1982 when a further seismic reflection line will be surveyed intersecting the western end of the MOIST line, continuing southwards to the west of the Outer Hebrides, then through the North Channel between Ireland and Scotland into the Irish Sea.

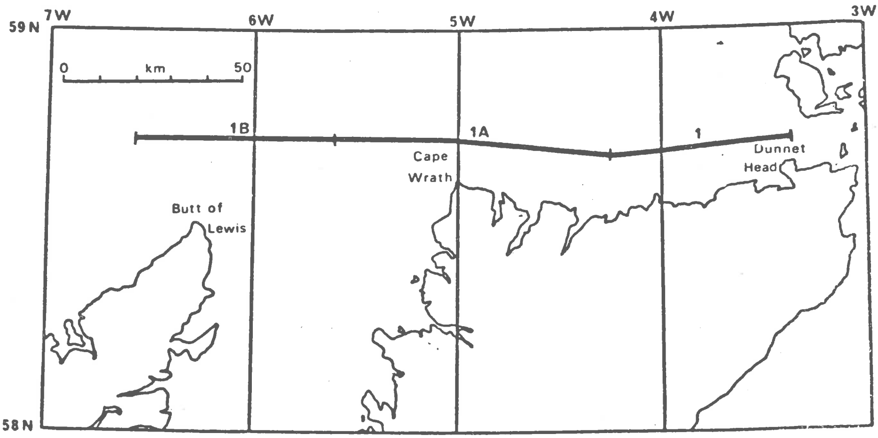
7 A Dobinson, D K Smythe and R McQuillin. 1982. The MOIST seismic data package. Marine Geophysics Unit Report No. 126, Inst. geol. Sci. 9pp.

This report describes the contents of a released package of the MOIST seismic data. Copies of this Report and conditions of sale along with costs of purchase of the data can be obtained on application to:

R McQuillin
Head of Marine Geophysics Unit
Institute of Geological Sciences
Murchison House
West Mains Road
Edinburgh EH9 3LA
Scotland

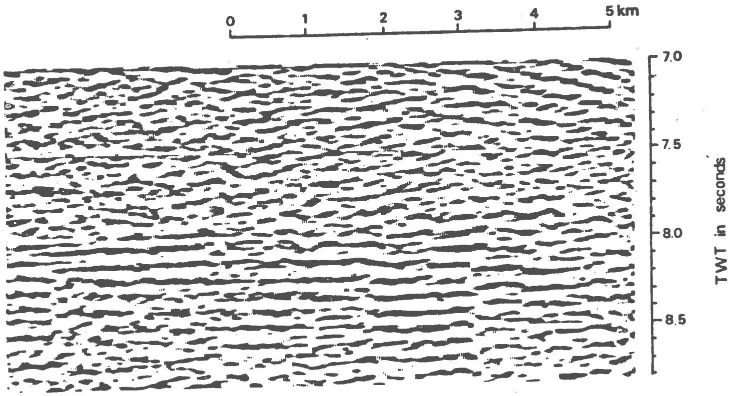
Other publications are in preparation.

8



Map showing location of the MOIST profile

9



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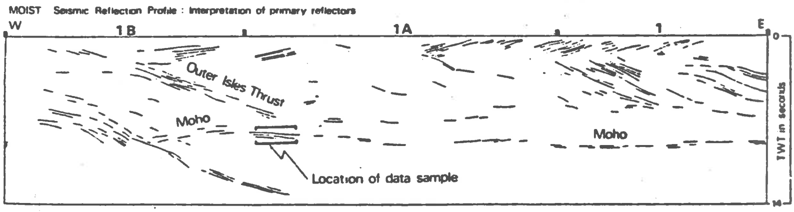


11 BIRPS was initiated in 1980 at a meeting of the Royal Society's Explosion Seismology Working Group with the object of formulating a UK programme of deep seismic reflection profiling and of stimulating as well as co-ordinating research in this field. The UK Natural Environment Research Council (NERC) agreed in 1981 to support the BIRPS programme in principle. The MOIST line is the first project to be funded as part of the BIRPS programme. A line has been planned for 1982 (see 6 above) and programmes for 1983 and 1984 are under discussion, work in 1983 being an as yet to be specified marine programme offshore SW Britain. A BIRPS core group has been set up in Cambridge (Director: D H Matthews). An advisory committee (BIRPSAC) chaired by Professor Blundell has the function of reviewing an annual programme of work in terms of the scientific merit of projects proposed by universities and institutions. Future work may include acquisition of land profiles as a follow up to work at sea.

YUGOSLAVIA (Geophysical Institute,Beograd;prof.T.DRAGASEVIC).

1. CRUSTAL STRUCTURE INVESTIGATION BY DEEP SEISMIC SOUNDING IN YUGOSLAVIA

2. 1980 - 1982

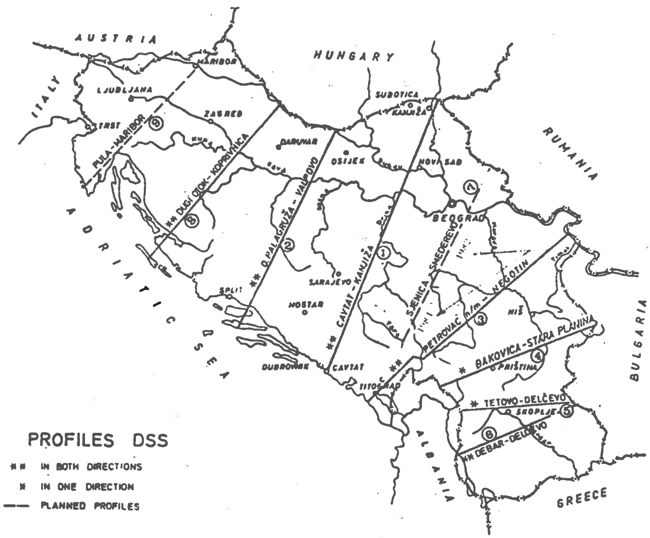
3. GEOPHYSICAL INSTITUTE-Beograd(Prof.T.Dragasevic,eng. B. Andric).
GEOFIZIKA - Zagreb (Eng. P. Joksovic).

4. In the course of 1981 were continued investigations of the Earth crust along the profile Sjenica-Rudnik (7) from a shot point situated in the Adriatic sea. To the end of 1982 the profile will be investigated to the Danube river.

Beside this line, in 1981 were realized the investigations of crustal structure by DSS along the profile Dugi Otok-Virovitica (8) in the lenght of 400 km using a few shot point. The most northeastern part of profile was realized in collaboration with Hungarian Geophysical Institute Roland Eötvös, Budapest using reciprocal number of shotings on the territory of Yugoslavia and Hungaria.

The investigations were carried out continualy using three seismic digital stations DFS-IV with distance between geophons 150m.

5. It was planed the profile Pula-Maribor (9) to be realized to the end of 1983 and the profile Djakovica - Stara Planina (4) to be finished to the end of 1954.



S U P P L E M E N T

R A P P O R T° (Prof. Dragutin Prosen)

CONCERNANT L'ACTIVITÉ DU GROUPE DE TRAVAIL POUR L'EUROPE DE L'EST DE LA SOUS-COMMISSION POUR LES SONDAGES SÉISMIQUES PROFONDS DE LA COMMISSION SÉISMOLIGIQUE EUROPÉENNE PENDANT LA PÉRIODE 1980-1982

D'après les rapports nationaux, on présentera un petit aprçu sur les travaux effectués dans ladite période. Malheureusement, jusqu'au moment de la compilation de ce rapport on ne dispose pas du rapport de la R.Allemagne Democratique et de la R.P. Pologne, tandis que pour l'URSS on dispose seulement d'un rapport concernant les travaux incl.l'année 1981.

R.P.Bulgarie

Les experts bulgares et soviétiques ont effectué des recherches le long du profil international VII (section Petrič - Nikopol), employant dix équipements séismiques portables "Čerepaha" enregistrant des ondes P et PS provoquées par tremblements de terre et des ondes provoquées par explosions de 7 points de tir, da même que par explosions dans la carrière "Medet". Les matériaux des enregistrements sont en couss d'élaboration.

On prolonge le profil des sondages séismiques profonds Debar - Titov Veles - Delčevo - Blagoevgrad - Pazardžik, qui a été réalisé par une collaboration entre les experts yougoslaves et bulgares, jusqu'à Burgas.

En 1981 ont été réalisées des recherches par sondages séismiques profonds employant des ondes réflechies dans la région de Sofia et aussi au "shelf" de la Mer Noire.

R.P.Hongrie

Les sondages séismiques profonds le long du profil près du Balaton ont été continués et l'élaboration des résultats obtenus est en cours

On a élaboré les résultats obtenus par mesures de réflexion à grande profondeur dans le territoire Debrecen - Biharkeresztes. Le profil a coupé une jeune zone tectonique.La discontinuité de Mohorovičić et la surface du LVL (Low Velocity Layer) ont donné bones réflexions. Dans la croûte terrestre on peut observer une zone disturbée d'une forme radiale et dans le manteau supérieur des faibles plissages et une faille profonde qu'on peut suivre au-sessus de la discontinuité de Mohorovičić. D'après ce fait on porrait conclure que la structure, qu'on porrait voir dans une coupe verticale, se soit formée sous l'influence des tensions horizontales.

° received 12 July 1982.

R.S.Roumanie

Plusieurs méthodes ont été utilisées pour obtenir in-formations à grande profondeur dans la lithosphère, soit: des registrements des réflexions aux grands temps obtenus par la pr pection pour le pétrole, des travaux de réfraction avec l'enre-gitrement des explosions dans les carrières et l'utilistion de sismogrammes obtenus dans le réseau séismologique de la Rouman

Les enregistrements des réflexions aux temps de 10 - secondes ont été effectués dans la Plateforme Moesique (au nor du Danube), dans la Dépression Précarpatique et dans la Dépres-sion Pannonienne. Dans la Plateforme Moesique la croûte terres a une épaisseur plus grande à l'est (nord Slobozia, 36-37 km) qu'à l'ouest où elle a des valeurs de 29-31 km (zone de Craiov La zone de transition croûte- manteau supérieur a un développe réduit (2-3 km). Dans la Dépression Précarpatique la croûte te restre est plus mince (36-37 km) au nord de la ville Ploeşti e plus épaisse à la curbure des Carpates (40-41 km, dans la régi Buzau). La zone de transition croûte-manteau est ici aussi plu épaisse (4-8 km). Dans la Dépression Pannonienne la croûte a u épaisseur de 26-28 km (zone de Carei) et une zone de transitio mince (2-3 km).

Les travaux de réfraction ont été effectués dans la brogea (zone des schistes verts) le long de trois profils en u lisant des explosions dans une carrière, située au nord de Con tantza. Les études s'y poursuivent.

En 1981 on a travaillé (collaboration entre les expe soviétiques, roumains et bulgares) le long du profil internati nal VII (Vinitza - Vrancea - Medet) en enregistrant à des dis-tances de 210-350 km l'arrivée des ondes provenantes du point tir Vinitza. Ces travaux se poursuivront aussi en 1982.

R.S.Tchécoslowaquie

On a poursuivi la recherche de la discontinuité de M horovišić à l'aide des enregistrements des ondes provoquées pa explosions dans les carrières. Une nouvelle carte de la discon tinuité de Mohorovičić pour le territoire de la R.S.Tchécoslo-waquie sera construite pendant cette année.

La méthode séismique de réflexion- couverture multip a été appliquée sur le profil 1/80 d'une longueur de 15 km dan la région des Hautes Tatras. Les résultats ont donné la possit té d'étudier la structure de la croûte terrestre jusqu'à une p fondeur de 40 km.

La séismique de réfraction a été appliqué le long de profils K I et K II (d'une longueur totale de 350 km) dans les Carpates Occidentales. Les résultats obtenus ont été élaborés.

L'URSS

On a continué les études de la composition de la croûte terrestre profonde et du manteau supérieur dans la région Carpato-balkanique par méthodes séismiques, spécialement par sondages séismiques profonds: on a continuié les travaux au terrain pour obtenir nouvelles dates expérimentales, de même on a étudié questions théoriques, ainsi que des méthodes pour l'élaboration des matériaux reçus par mesures. Dans la Plateforme Européenne de l'Est ont été exécutées recherches séismiques détaillées pour compléter les résultats régionals reçus plus tôt, qui concernent la composition de la lithosphère. Ces travaux ont été exécutés le long des profils d'une longueur 200-300 km, qui étaient parallèles ou perpendiculaires à la géotraverse internationale IV (profil VIII) au territoire du bouclier ukraînien dans la région de Kanev, Nikolaev, Tcherkassi et au. On a élaboré trois profils.

On a continué les recherches le long de la géotraverse VI (Mer Baltique - Mer Noire).

GERMANY F.R.°

Institut f. Geophysik, Universität, München

E. 1 Bohemian massif
. 2 July 1982
. 3a Geophysical Institute Munich
. 3b Other German Geophysical Institutes
. 4 Crustal structures of the western margin of the Bohemian massif
. 5 Crustal thickness 32-34 km with a distinct intracrustal discontinuity at ca. 20 km

Institut für Geophysik, Universität Karlsruhe

F. 1 Southern German triangle
. 2 June 1982
. 3a Geophysical Institute Karlsruhe
. 3b Other German Geophysical Institutes
. 4 Crustal structure southern Germany

° received 16.7.1982

I. Geophysik, Univ., Hamburg (prof. J. Thiessen)

G. 1 Development and testing of a new ocean-bottom-seismograph in the field of hydrocarbon exploration

. 2 03.1981

. 3 IFG, Hamburg

. 5 Offshore refractionseismic measurements on 3 profiles (60 km each) with 20 ocean bottom seismographs and 12 Mars 66 stationsonshore. About 100 shots of 12,5 kg have been fired on each profile.

. 6 The structure of the sediments to the cristalline basement in about 7 km depth has been delineated. Salt formations have been penetrated.

H. 1 SIMA 80

. 2 06 -07 1980

. 3 IFG Hamburg, OGS Trieste

. 4 Offshore refractionseismic measurements on 3 profiles (about 130 km each) with 6 ocean-bottom-seismographs. 312 shots with charges between 25 kg and 3x100 kg (dispersed charge)have been fired.

. 5 In work.

I. 1 Determination of the factors controlling chromite mineralization, with special emphasis on aid to mineral exploration.

. 2 01.81-04.81 Oman 02.82-05.82 Greece

. 3 IFG, Hamburg

. 5 Application of different geophysical methods (magnetic, gravity, geoelectric, VLF) over well-known chromite deposits.

. 6 There is a chance of finding chromite by looking for magnetic anomalies in a fast survey and explore these areas with a narrow spaced gravity survey afterwards.

. 7 Measurements of the susceptibility of chromite deposits in new Caledonia in autumn 1982.

. 9 Laboratory measurements and comparison of the results from different areas.

L . 1 <u>Red sea (Egypt)</u>

. 2 Spring 1981

. 3 IFG, Hamburg

. 4 Helwan observatory of astronomy and geophysics, Cairo, Egypt.

. 5 A combined onshore-offshore refractionseismic study of the crustal structure in the northwestern part of the Red sea.

. 6 The thickness of the Crust in the Western shelf area of the Red sea varies between 16 and 18 km. The P-wave-velocity of the upper mantle is about 7.6 to 7.8 km/sec.

M. 1 <u>Red sea (Saudi Arabia)</u>

. 2 Spring 1981

. 3 IFG, Hamburg

. 4 Faculty of earth sciences, King Abdulaziz University Jeddah, Kingdom of Saudi Arabia.

. 5 A combined onshore-offshore refractionseismic study of the crustal structure in the northeastern part of the Red sea.

. 6 The crustal thickness of the eastern shelf area of the Red sea varies between 16 and 18 km. The P-wave-velocity of the upper mantle is about 7.6 to 7.8 km/sec.

. 8 Crustal structure of the North-Western region of Saudi Arabian peninsula and its transition to the Red sea. To be printed in "Pan - African crustal evolution in the Arabian Nubian shield, No. 13"

N. 1 <u>Morocco 1980</u>

. 2 01.-02.1980

. 3 IFG, Hamburg

. 4 Ministere de l'energy et des mines, direction de la geology, Rabat, Morocco, University Mohammed V, Institut Scientifique, Service de Physique de Globe, Rabat, Morocco.

. 5 Deep seismic soundings were performed with a total of 28 stations of mars 66 type in regions of the anti atlas, the high atlas and the meseta. These measurements were connected with cruise 53 of rv "METEOR".

. 6 The thickness of the crust varies between 26 km on the coastal region of southern Morocco and 36 km beyond the high atlas mountains. A submoho-refractor was found in a depth of about 53 to 55 km. The overburden reaches a maximum thickness of 3 km in the sous-trough.

O. 1 METEOR 53

. 2 01.80

. 3 IFG, Hamburg

. 4 Centre Oceanologique de Bretagne, Brest, France

. 5 Offshore refractionseismic measurements on 3 profiles (100 km to 300 km length) with 4 ocean bottom seismographs. 280 shots with charges between 25 km and 3x100 kg have been fired.

. 6 At the continental margin off Morocco an abnormal velocity of the upper mantle of about 7.3 km/s was observed. The crustal thickness varies there from 12 to 15 km

P. 1 <u>North Agean trough</u>

. 2 09.1980

. 3 IFG, Hamburg

. 5 Combined onshore-offshore reflection- and refraction seismic survey and offshore magnetics

. 6 Thermaikos Gulf: observation of Plio- and Miocene basis of 1.0 km (NW) and 2.0 km (SE) for Pliocene (wave-velocity : 1.85 km/sec) and 3.0 km (NW) to

5.0 km (SE) for Miocene (VP = 2,7 km/s).
A velocity of 5.5 km/sec has also been observed and is interpreted as triassic limestones of the Vardar zone. Sporades basin (south of Chalkidici): beneath a thin sediment layer of some hundred meters a P-wave -velocity of 5.7 km/sec has been observed. It will be analysed whether this layer belongs to the Vardar zone or to the Rhodope massiv.

Q. 1 Seismic attenuation in marine sediments

. 2 09.1981

. 3 IFG, Hamburg

. 5 Offshore refractionseismic measurements on 3 profiles of maximum 12 km length with 6 ocean-bottom-seismographs in a waterdepth of about 30 m. Total: 192 shots with charges of 100 g, 200 g and 1.000 g have been fired.

. 6 The evaluation of the first arrivals led to a 3-layer -model, with P-wave-velocities between 1.9 km/sec and 3.3 km/sec, the depth to the top of layer 3 was 2.5 km.
The analysis of the dispersion of the surface-waves yields two modes with velocities about 190 m/sec and 380 m/sec for frequencies of 4 to 7 Hz.
After correcting the effects of the geometrical spreading, an attenuation coefficient of = 0,7 (1 km) related to 5,7 Hz for the slower mode cound be estimated.

Bundesanstalt für Geowissenshaften, Hannover

R. 1 Hessian depression

. 2 Sept. 1981

. 3a Geological survey Hannover

. 3b Other German Geophysical Institutes

. 4 Topography of the basement top

I N D E X

RAPPORT SUPLÉMENTAIRE

CONCERNANT L'ACTIVITÉ DU GROUPE DE TRAVAIL POUR L'EUROPE DE L'EST DE LA SOUS-COMMISSION POUR LES SONDAGES SÉISMIQUES PROFONDS DE LA COMMISSION SÉISMOLOGIQUE EUROPÉENNE PENDANT LA PÉRIODE 1980 -1982

D'après les rapports reçus en retard de la R. Allemagne Democratique et de l'URSS on présente ce rapport suplémentaire.

R.Allemagne Démocratique

Les recherches séismiques digitalisées dans le sud du pays, l'enregistrement des ondes provoquées par les explosions dans les carrières et l'enregistrement des ondes pendant la réalisation du projet Fenno-Scandinavien internatioanal exigaient un changement des appareils séismiques adoptés pour l'enregistrement sur stations mobiles et fermes. De même on a développé un appareil pour l'enregistrement du moment de tir.

On a étudié questions théoriques, ainsi que des méthodes pour l'élaboration des matériaux reçus par mesures au terrain.

Les méthodes que Knothe a éprouvé sur le profil STS VI pour dériver les fonctions vitesse-profondeur d'après les dromochrones, ont été appliquées sur les matériaux reçus le long des profils et on a reçu des fonctions vitesse-profondeur comme base très importante pour le calcul des profondeurs le long des profils séismiques digitalisés.

L'URRS

Sur la partie septentrionale de la géotraverse I (péninsule Kola - Kaliningrad - Prague - Alpes) ont été réalisés des sondages séismiques profonds à partir de la Mer Barencev vers la ville Kostomukshi. En 1982 ces travaux seront accomplis.

Sur la géotraverse II (péninsule Kola- Leningrad-Gomalj-Mer Adriatique) ont été réalisées des recherches séismiques dans la partie septentrionale du progil et dans la région de Pripjat.

Sur la géotraverse III (Vokruta- Harkov-Crimée) a été réalisée une réinterprétation des vielles dates séismiques da la partie méridionale du profil.

Sur la géotraverse IV (Taganrog-Kirovograd- Lvov-Vroclav-Berlin)des recherches géophysiques complexes ont été effectuées dans le bouclier ukraînien et dans la zone Teisseer.

Sur la géotraverse V (Krasnodar-péninsule Tarahankutsk-Vraancea- Budapest-Pra ue-Perlin) ont été effectuées des recherches séismiques dans la partie Crimée- Vrancea par une collaboration entra les experts soviétiques et roumains. On a pu recevoir des reflections des horizons profonds 100-150 km.

Le long la géotraverse VI (Mer Noire - Mer Baltique) on réalise les recherches par les experts sovjétiques et polonais. Le profil commence dans la région séismoactive de Jalta, coupe la péinsule Crimée, la partie occidentale du bouclier ukraïnien, le territoire de la Pologne et fini dans la Mer Baltique.

D'après les résultats d'interprétation provisoire l'asthénosphère dans la partie occidentale du bouclier ukraïnien se trouve à une profondeur de 140-150 km et dans la région d'Odessa à 200 km. Dans la région de la steppe de la Crimée on a pu constater une couche dans laquelle la vitesse de propagation des ondes est 7,5-7,6 km/s, ce qui est caractéristique dans les régions tectoniques actives.

Sur cette géotraverse on a planifié d'effectuer des sondages magnétotelluriques et ensuite de faire une interprétation complexe de tous les résultats géologiques et géophysiques.

Sur la géotraverse VII (Vinitza- Vrance-Sofia- Rodhopes) dans la partie Petrič-Nikopol les experts sovjétiques et bulgares ont effectué des recherches employant des équipements séismiques "čerepaha". Les experts roumains ont réalise des recherches le long d'une partie de cette géotraverse.

On planifie de finir en 1983-84 les travaux du terrain et l'élaboration des résultats obtenus le long des géotraverses VI et VII, tandis qu'en 1985 on effectuera les travaux le long la géotraverse VIII (Kirovograd-Dobrogea- Burgas).

Dans la période 1980- 81 on a effectué et on effectue le long des géotraverses recherches en employant différentes méthodes géophysiques pour povoir étudier la lithosphère d'après une interprétation complexe des résultats obtenus par plusieurs méthodes géophysiques.

Dans le but d'explorer la partie supérieure de la croûte consolidée on réalise des recherches séismiques par la méthode CDP dans le bouclier ukraïnien, en Bulgarie, Roumanie et au.

Pendant la période 1980-82 ont été publiées deux monographies: 1. La structure de la croûte terrestre dans l'Europe Centrale et l'Europe de l'Est d'après les résutats géophysiques,- "Naukova Dumka", Kiev, 1980. Redacteurs: V. Sollogub, A. Guterch, D. Prosen.

2. Tectonosphère de l'Ukraïne et des autres régions de l'USSR,- "Naukova Dumka", Kiev, 1980. Redcteurs: V. Belousov, V. Sollogub, A. Čekunov.

Report of Meetings on KRISP 84 held during the Leeds EGS, Aug 1982.

PRESENT. M.A.Khan, I.A.Hill (Leicester), R.E.Long (Durham), J.D.Fairhead (Leeds), K.Fuchs, C.Prodehl, J.Mechie (Karlsruhe), J.Wohlenberg (Aachen),S.Mueller, J.Ansorge, E.Banda (Zurich), C.Lund, B.Kullinger (Uppsala), K.Olsen (Los Alamos), R.Keller (El Paso), and C.J.Swain (Nairobi).

BACKGROUND. MAK began by referring to the report of the meetings in San Francisco in December 1981 which explained the background to KRISP 84. The time-table outlined in that report envisaged a visit to Kenya in August 1982, discussions during the Leeds EGS, and the preparation of a proposal by Nov 1982 for submission to the various national funding bodies. The general aim at that time was do three 600km profiles- 2 parallel to the rift and one across plus a few shorter cross lines where possible. The long lines would have shots at 200km intervals and recording stations at 2km intervals. The shorter lines would have smaller shot and station intervals.

This was discussed further at a meeting in Leicester on July 12 1982.

It was noted that this programme would involve working in very remote areas and the cost would be prohibitive. Experiences with receiving large charges at large distances in other parts of the world had not been encouraging. It was felt that attention should be given to obtaining detailed information within and close to the rift with close shot and receiver spacings and to considering reflection more seriously than hitherto. Therefore a better programme would be:

(a) An E-W line, 400km long across the rift from Kisumu eastwards through to Isiolo with an average shot interval of 50km (range 15km-100km) and a station spacing of 2km.

(b) A N-S line 250km long along the rift axis from Nakuru to Lokori with shot and receiver spacings as in (a).

(c)A N-S line 250 long parallel to the rift axis but to the east going northwards from Isiolo with shot and station spacings as in (a).

Desirable optional extras would be:

(d) A N-S line 130km long from Nyeri to Suguta Mugie.
(e) A N-S line 130km line from Timboroa to Kitale.
(f) An E-W line across the rift through Marigat.
(g) A NW-SE line across the rift from Sigor-Tot-Kingyang-S.Mugie.
(h) An E-W line across the rift through Narok.

On July 13 this programme was discussed with Professor Shackleton who seriously questioned the choice of the main E-W line from Kisumu-Isiolo. It followed the line of the Kavirondo rift,went through complex large volcanic region where it met the Gregory Rift, and went rather close to Mt Kenya which was known to have large deep conductivity anomalies. In his view we should concentrate on extending (f) and (h) above in both directions. Extensions to the west had the additional merit of crossing a major N-S ophiolite thrust belt which would be an exciting reflection target as it probably extends northwards to Egypt and downwards through the MOHO.

PLANNING VISIT TO KENYA IN AUGUST 1982.

A 2-week visit to Kenya was made in early August by M.A.Khan, A.Pointing (Leicester), D.H.Griffiths, R.F.King (Birmingham), K.Olsen (Los Alamos), and R.Keller (El Paso) to discuss the programme with the Kenyan authorities and do a reconnaissance over the proposed lines by road and air. Discussions were held with the administrators at the Office of the President from which the Research Permits are issued, the National Council for Science and Technology which co-ordinates research programmes and provides support for local participants, the Department of Mines and Geology whose support is necessary to obtain the research permit and also issues the permits for the purchase, transport, storage and use of explosives, Dr Viktor Kahr the UN Geology co-ordinator for Africa, and Mr Wairegi, the chief geologist at the Department of Energy. The meetings went well despite the disorganisation resulting from the attempted coup the previous week. Dr Gacii who participated in the 1968 Birmingham-Leicester experiment was now head of the NCST and also had an office in the President's office. He and his assistants were most helpful and cooperative. The Kenyans are as anxious as ever to increase overseas goodwill and collaboration.

The second week was spent on a field reconnaissance by road from Nairobi westwards to Narok and Migori, along the favoured E-W line, then N to Kisumu, Eldoret, and Kapenguria, and east and south to Kingyang-Hannington-Nakuru along the N-S rift line.From Nakuru we did a 1500km aerial reconnaissance along the rift to Lake Turkana and returned via Marsabit towards Mt Kenya over the third line. The general conclusions of the group were that:

(a) Two major profiles should be attempted _ the E-W line across the rift from L.Victoria through Narok to Garissa so that some crustal information outside the rift may be obtained as well as the structure of the rift itself. The second line would be along the rift axis from Lokori to Magadi if possible.

(b) Additional lines should be considered if the funds became available e.g. an E-W line through Eldoret and Baringo and a N-S line between Archers Post and Marsabit.

It was emphasised that the programme should involve a preliminary phase with a few instruments and experiments on land and in water.

KRISP 84-85

The above proposal was put to the meeting for discussion with a rough estimate of £500,000 for deployment and operating costs in Kenya and the assumption that each participating group will be responsible for the costs and operation of its own stations and a contribution to central costs (mainly shots). The German (including Professor Illies who had died only two weeks previously) group had also done some independent thinking and costing . Although all the groups were interested in the experiment only the US, Germany, and the UK seemed likely to raise initial support. The US and German groups also reported that their responses will not be available before late in 1983. For this and a variety of other reasons the preliminary experiments could not be carried out before the summer of 1984 and the main experiment in 1985. KRISP 84 would now become KRISP 84-85.

There was considerable debate about some parts of the programme. Some felt that the highest priority should be given to the long axial line but the value of a long line was questioned. It would give an expensive velocity-depth model in the middle if it were straight. There was an argument for shorter lines. The point was settled by agreeing to the long line to get the deep information but with more shots along it for the upper crustal information. There were also doubts about our ability to interpret the data from a cross-line. It was emphasised that a major objective was to obtain a cross-section of the lithosphere across the rift and that therefore the cross-line should have the highest priority. The results from the Cambridge group across the Viking Graben reported elsewhere at the meeting had been most encouraging. Another view was that the line outside the rift was most likely to give clear unambiguous results and should therefore be ?the first priority. It was also argued that the starting point should be the Durham model based on the Kaptagat array data and that the programme should set about refining and extending it. The contrary view was that the refraction data should provide the starting point and be used to control the models based on earthquake data from Kaptagat and KRISP-81 and the gravity data. MAK, CP, RK, and KO were asked to prepare a revised programme taking the points raised into account. After informal discussions during the next two days the following programme (Fig 1) with costings based on information obtained on the Kenyan visit.

1984. One shooter from each country (US,Germany,UK) plus six observers (2 per country) with recording equipment should experiment with shots on land and in water at various ranges. Other participating countries should also send leading observers for this trial. It is likely that Dr B. Jacob who fired dispersed underwater charges for the LISPB experiment would join in this phase.

1985. (1) An axial rift line with stations occupying the 310km section between Lokori (LOK) and Naivasha (NAI). Shots would be fired at Lokori, Kapedo (KAP), Bogoria (BOG), and Naivasha. Off end shots would also be fired at Ferguson's Gulf (FG) in Lake Turkana and Magadi (MAG) which are 590km apart.

(2) An E-W line 350km long across the rift betweem Lake Victoria and Thika. Shots would be fired near Lake Victoria (VIC), Narok(NAR), and Thika (THI).

(3) An off-rift N-S line 250km long from Marsabit (MAR) to Isiolo (ISI) with some additional stations in an arc to the south of Mt Kenya.

(4) A short trial line with stations at .5km intervals across the rift eastwards from Narok. This would provide valuable information on the near-surface structure across the rift while serving to test equipment at a location close to the Nairobi HQ.

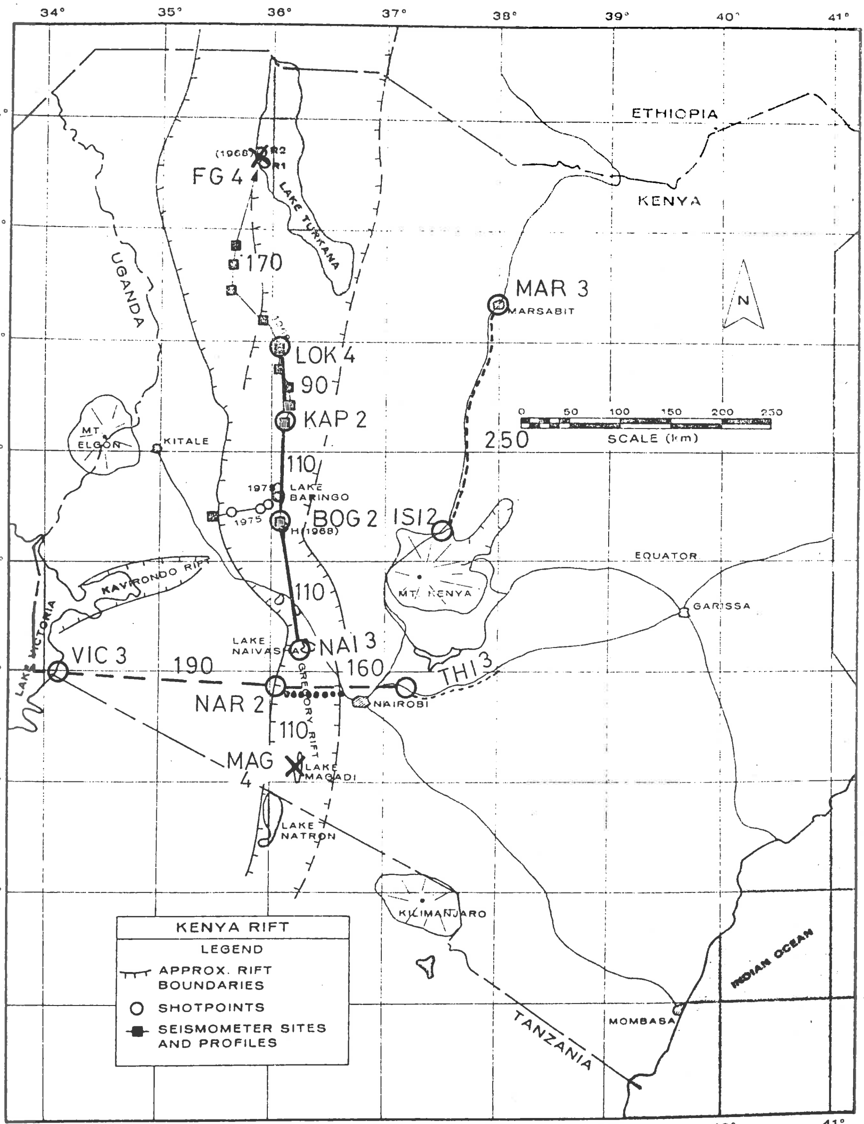
This programme was approved at a final meeting as being the best that could be formulated at the present time. There would no doubt be refinements and modifications when more information on funding and participation became available.

NOTE. This programme was outlined to the assembly in a poster session and in a talk in the Deep Seismic Sounding session. Further interest in recording was expressed by the USSR, Finland, Poland and Italy.

MAK

20/10/82.

FIG.1 KRISP 84 - 85



O SHOT POINTS SIZES IN TONNES

X OFF - END SHOT POINTS

••••••• STATIONS AT 0·5km (Trial)

STATIONS AT 3Km

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EGS-ESC ASSEMBLY 1982 AT LEEDS, ENGLAND

S3. SYMPOSIUM ON EARTHQUAKE PREDICTION RESEARCH
REPORT OF HIGHLIGHTS

This was the first symposium organized by the Subcommission on Earthquake Prediction Research established in 1980 by the European Seismological Commission. The response to this symposium was remarkably good. Although some speakers, mainly from Eastern European countries, were unable to attend, thirtyone research papers were presented and a panel discussion was held on "strategies for earthquake prediction".

The chairman of the subcommission summarized the historical development of earthquake prediction research in Europe which turned out to be essentially the earthquake prediction research in the USSR, dating back even to the days of B. Galitzin. In recent years considerable activities, stimulated in part by an initiative of the Council of Europe, are under development in western European countries. A catalogue, compiled by the subcommission, informs on current projects and plans. Scientists from as many as seven countries are or will be involved at the North Anatolian Fault zone and three countries in Greece.

Beginning in 1984 crustal movements in the eastern Mediterranean area will be monitored by repeated high precision satellite laser ranging using mobile stations. Observations of earthquake precursory phenomena are still limitet in western Europe but techniques to measure and to evaluate seismic velocity variations by millisecond earthquake seismology, magneto-seismic effects, radon emanation, and self potential measurements are advanced. The surprisingly high consistency of earth current anomalies, observed 6 to 8 hours before shocks of $M \geqslant 2,7$ in Greece was vivaciously debated with the authors. In the new phase of

In the new phase of earthquake prediction research in the Soviet Union, starting in 1982, mobile multidisciplinary observatories for seismometriec, magnetometric, gravimetric, geodetic and geochemical measurements will play an essential part. Electric and electrotelluric measurement will probably be incorporated in future. The stations will remain at one site for several months and will reoccupy the same site usually after a few years or earlier, if desirable.

Several papers covered the influence of external sources on the occurence of earthquakes such as tidal forces, surface loading by water or athmospheric pressure, and cosmic factors.

The great majority of the papers, however, was dealing with the search for regularities in the space-time distribution of earthquakes with regard to medium or long termin prediction. It seems that seismic gaps of first or second kind (after Mogi) are indicated in a number of cases but the situation is complicated by the complex stress pattern of the Alpine-Mediterranean collision zone.

The panel discussion in which the major countries with experience in earthquake prediction research were represented (USA, USSR, China, Japan) gave an opportunity to the participants from European countries to get first hand information from the experts on the systems for collecting and evaluating observatinal data on earthquake precursors and on the criteria (as far as spezified) on which decisions on earthquake predictions are based. The problem of unqualified predictions was raised and it was recommended that for the scientific advice of governments in case of doubtful predictions an European advisory committee on earthquake predicitions may be established by the Council of Europe with the help of the European Seismological Commission. The panel discussion ended with the question to the experts for places with high potential for a strong earthquake in near future in their respective countries. For the sake of the speakers the answers will not be reproduced here.

H. Berckhemer
Convenor of the symposium

SUBCOMMISSION ON EARTHQUAKE PREDICTION RESEARCH (SCEPR)

Minutes of the Business Meeting, Leeds, U.K., 27 August 1982

The meeting was opened by Prof. Berckhemer, the Chairman of the Sub-Commission, who welcomed attended members of the commission and observers (see Appendix 1). He introduced the draft agenda. It was discussed and adopted as follow:

1. Short discussion on present symposium
2. Publication of the papers
3. Membership of the SCEPR
4. Approaching IASPEI - Commission on Earthquake Prediction for 1983
5. Discussion on Dr. Hedervari's proposal
6. Recommandations
7. Any other business

1. Short discussion on present symposium during EGS-ESC meeting

Prof. Berckhemer opened discussion on the symposia and asked to the member their point of views concerning the papers presented in earthquake prediction symposia. He also thanked the efforts of the chairmen of individual sessions in this symposia.

2. Publication of the papers

The discussion was opened for the publication of the papers presented in the symposia. It was decided that some of the presented papers which have not been published before in one of the international journals are intended to be published in a special volume.

It was noticed that the Sub-Commission of Earthquake Prediction Research had got offers from several publishers.

The Subcommission favours to publish the papers in "Journal of Earthquake Prediction Research" as a first choice and in "Pageoph" as a second. Prof.Berckhemer would make necessary approaches to these publishers.

The Subcommission agreed that the editors of the special issue for these proceedings of the Leeds earthquake prediction symposium will be H.Berckhemer and A.Mete Isikara.

The Subcommission agreed that chairmen of the individual sessions would make recommendations for the selection of papers and Prof. Berckhemer would invite the individual authors to submit their manuscripts by 1. January 1983. The papers have to pass a usual reviewing procedure before being accepted for publication.

3. Membership of the Subcommission on Earthquake Prediction Research

The following persons were proposed as new members and adopted by the SCEPR

D. Sokerova	Bulgaria
P. Burton	U.K.
M. Pantovic	Yugoslavia

The complete list of the members of the SCEPR is given in Appendix 2.

4. Approaching IASPEI - Commission on Earthquake Prediction

If Prof. Rikitake intends to hold a symposium on earthquake prediction in Hamburg during the 1983 IUGG General Assembly, the SCEPR offers to cooperate and to co-sponsore this symposium.

5. Discussion on Dr. Hedervari's proposal

According to discussions at the meeting, the SCERP decided to establish a Project on Collection and Evaluation of Data on Earthquake Light Phenomena at the Subcommission and asks Dr. Hedervari to take the necessary steps to start this activity. He may write relevant scientists on behalf of the SCEPR. The Sub-commission realized that this could only be a preliminary solution, because of the global character of the project.

6. Recommendations

The SCEPR made 3 recommendations which were presented and approved at the final planery session in ESC (see Appendix 3).

APPENDIX 1

Attendance

Members present:

H. Berckhemer (FRG), A. V. Nikolaev (USSR), A. Mete Isikara (Turkey). B. C. Papazachos (Greece), C. Radu (Romania), R. Scarpa (Italy), L. A. Mendez-Victor (Portugal), R. Meissner (FRG)

Observers present:

A. Gvishiani (USSR), J. Zschau (FRG), H. Friedmann (Austria)

APPENDIX 2

The members of the Sub-Commission on Earthquake Prediction Research

H. Berckhemer	FRG	Chairman
A. V. Nikolaev	USSR	V. Chairman
A. Mete Isikara	Turkey	Secretary

P. Burton	U.K.
L. Drumia	USSR
E. Hurtig	GDR
R. Meissner	FRG
L. Mendez-Victor	Portugal
J. Mezcua	Spain
St. Mueller	Switzerland
I. L. Nersessov	USSR
M. Pantovic	Yugoslavia
B. C. Papazachos	Greece
G. Pupinet	France
C. Radu	Romania
R. Scarpa	Italy
D. Sokerevo	Bulgaria
E. Sulstarov	Alabania
A. Vogel	FRG (as from former ESC "Geodynamic Techniques" Working Group)

APPENDIX 3

Recommendations

1. Being aware of the high responsibility involved in any kind of earthquake predictions, and to provide some scientific advice for goverments in case of doubtful predictions, it is recommended that an European Advisory Committee on Earthquake Predictions be installed by the Council of Europe with the help of the European Seismological Commission.

2. Considering the increasing efforts made by European countries in the field of earthquake prediction research ESC emphasizes the importance of a fast and centralized data acquisition and evaluation and encourages the European Mediterranean Seismological Center at Strasbourg to collect and disseminate data relevant to earthquake prediction problems.

3. The symposium on the earthquake prediction research at Leeds has shown that Western European Countries just begin to enter this field. First promising results however have already been achieved by multidisciplinary approach. It is still the subject of basic research with the aim of practical application in the future. These research works should be intensified and supported by the European Countries.

S C I E N T I F I C   P A P E R S

The 18th E.S.C. General Assembly

- S c i e n t i f i c   p r o g r a m m e -

The ESC and related programme consists of:

(a) SW 1 - Seismotectonics
S 2 - Lateral Heterogenity in the Mantle
S 3 - Earthquake Prediction
S 4 - Engineering Seismology
SW 21 - Filtering Analysis

(b) meetings of the ESC subcommissions:

SC 1 - Seismicity
SC 2 - Data aquisition
SC 3 - Physics of Earthquakes Sources
SC 4 - Microseisms and Seismic Noise
SC 5 - Theory and Interpretation
SC 6 - Deep Seismic Sounding
SC 7 - Earthquake Prediction Research
SC 8 - Engineering Seismology

(c) P 4a on Seismic Studies of the Crust and Upper Mantle (poster session) organized by the IASPEI Commission on Controlled Source Seismology

(d) CP: IASPEI Commission on Practice

EARTHQUAKE VULNERABILITY

N.N. Ambraseys (Civ. Eng. Dept. Imperial College of Science and Technology, London SW7)

Damage due to a particular earthquake is dependent on factors such as building type and population density as well as on the physical parameters of the earthquake itself. Where economic development is rapid the former factors can change considerably in the time between comparable events. It can be shown that for the North-Eastern Mediterranean it is possible to take account of these factors and obtain a correlation between total damage and earthquake magnitude for shallow, on-land earthquakes.

Fig. 1 shows the total damage (D) - surface wave magnitude (M) relationship for the region between 34° and 43° north and 19° and 44° east, normalised to a population density of 50/km², for different building types, e.g. R = rubble masonry; A = adobe; s or S = stone masonry; B and T = brick or timber-framed houses.

This figure shows that the major controlling factor of total damage is building type; it also explained why the destructiveness, and hence the Intensity of early events can be grossly over-estimated if damage is used as the sole criterion regardless of the building type exposed to an earthquake. This error is significant, particularly for events of low magnitude $4 \leq M \leq 6$.

An attempt to correlate damage with epicentral Intensity I_o showed that I_o alone is not a good predictor. This is obvious, since two shallow depth earthquakes of different magnitude may well produce the same epicentral Intensity; however, the larger of them will release more energy that will affect a larger epicentral area and consequently cause greater total damage.

Fig. 2 shows the percent total loss as a function of Magnitude for the 4 types of construction. These curves depict the high vulnerability of the substandard classes of construction R and A and the average resistance of classes s and S.

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(1) Ambraseys N. and Jackson, J. (1981) "Earthquake hazard and vulnerability in the North-eastern Mediterranean; the Corinth earthquake sequence of February-March 1981". Disasters , Vol. 5, No. 4, International Disaster Institute, London.

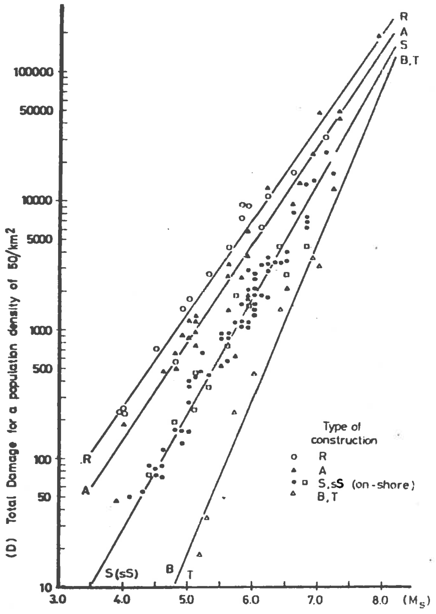

Figure 1.

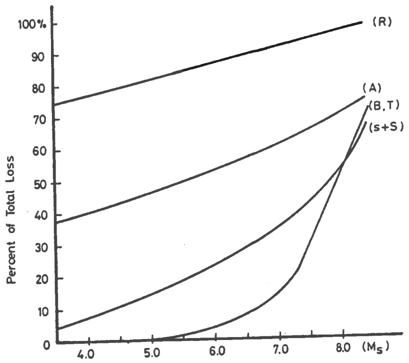

Figure 2.

UNDECENNIAL VARIATION OF MICROSEISMS

BERNARD,P.
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Abstract- Discovered in 1938 with a maximum during the decrease of sunspot activity, it has been searched on the more recent measurements gathered on microseisms, the monthly means of which were calculated: for each station, a yearly figure was referred to the mean of this station; these numbers have been separately averaged in successive years for all stations simultaneously available. The mean curve obtained (1) has a clear undecennial tendency, emphasized(curve 3) by a Labrouste linear combination filter; its amplitude is paradoxically at a minimum after the paroxysmal solar cycles of 1948 and 1958.

A theory is presented to explain this circumstance:the atmospheric disturbances which are the physical cause of microseims being fed by the difference of solar irradiance received by unit surface on the inter tropical zone and on the extratropical caps, this difference increases in the same proportion than the total energy when sunspots diminish, according to recent US astrophysical observations. This variation is of a correct order in comparison with the energy of additional atmospheric disturbances. Now, during highly sunspotted years, a deficit of solar heat will occur and the above increase will take place starting from a smaller difference of internal energy between warm and cold Earth zones, so that the undecennial effect is itself lessened.

Correlation with these results may be found in R.G. Currie's work on eleven years signal in the length of day, which decreases in the same ratio as the microseismic one around 1960 (curves 4-5). It is indeed known that earth's rotation is affected by atmospheric general circulation and a sun-weather effect becomes therefore apparent from such a correlation.

La question d'une influence éventuelle de l'activité solaire sur les microséismes rejoint celle de sa répercussion sur la météorologie et, comme telle,a soulevé et soulève encore le scepticisme des météorologistes. Cependant on remarquait déjà il y a 50 ans le retour d'un fort maximum de la moyenne annuelle des microséismes en 1930 après celui de 1920, dates postérieures de 3 ans au maximum des taches solaires, ce qui laissait supposer un retard analogue de l'intensité des cyclones et dépressions atmosphériques sur le cycle solaire.

Les observations récentes ont permis de poursuivre cette comparaison: on retrouve un maximum en 1940 à Venise, La Plata et Kew(dont les mesures non publiées ont été miraculeusement retrouvées au centre d'Edimbourg);à St Maur il ne se produit qu'en 1943 qui est aussi la date de la plus forte agitation magnétique. Les 2 cycles suivants sont moins nets et le maximum d'Uppsala a lieu en 1949, celui de Strasbourg en 1962 ainsi qu'à Varsovie, mais à partir de 1970 nous retrouvons une augmentation accentuée en 1972 à Rabat et Porto. Toutes ces dates interviennent pendant la phase décroissante de l'activité solaire. Notons tout de suite l'exception d'Honolulu qui parait en phase avec le cycle solaire: une explication peut être proposée d'après un fait signalé pour la première fois par M.Bath: la latitude moyenne des dépressions diminue au moment du maximum des taches et, pour une station de basse latitude l'effet inverse de la distance se superpose à celui de l'intensité des perturbations .Bath, puis Brown & John ont remarqué cela pour l'Atlantique et Honolulu le confirme pour le Pacifique.

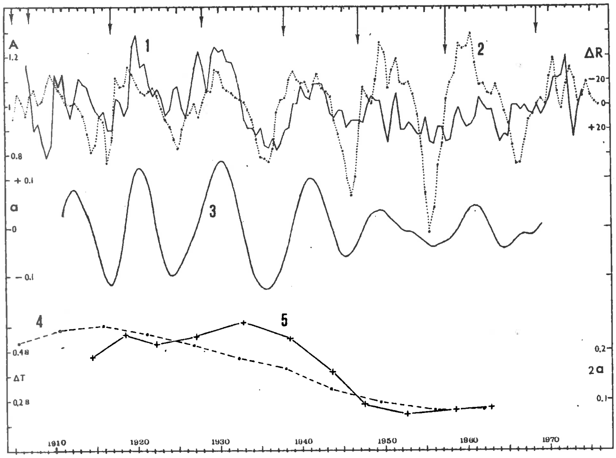
Afin d'avoir une représentation globale de la variation des microséismes, j'ai groupé les séries suffisamment longues d'observation pour 15 stations,la plupart européennes,et considéré leurs moyennes de 12 mois calculées 2 fois par an (jan.-déc. et Juillet-juin pour ne pas couper le maximum hivernal);chaque station ayant une moyenne générale M, chaque chiffre annuel A,B,C a été rapporté à M: $\frac{A}{M}$, $\frac{B}{M}$ sont une suite de nombres dont la moyenne est 1. Ils ont alors été groupés par année et une moyenne générale des stations disponibles a été obtenue pour chaque année,dont la suite est représentée par la courbe 1.

La coincidence de ses maximums avec ceux de la courbe 2 qui représente la variation ΔR des nombres de Wolf d'une année à l'autre est spectaculaire et suggère qu'une diminution des taches solaires provoque les perturbations atmosphériques qui à leur tour engendrent les microséismes

Isolons maintenant la variation undécennale de ceux ci par la méthode Labrouste, j'en rappellerai brièvement le principe: on effectue dans ce cas sur la suite des nombres biannuels la combinaison:

$s_1 = a + b + c = b_1$ qui efface les accidents de période 3 puis sur la suite obtenue la combinaison $s_2 = b_1+c_1+d_1+e_1+f_1 = d_2$ qui efface la periode 5 et enfin les combinaisons: $Z_3 = d_2-j_2 = g_3$ et $Z_4 = o_3-g_3$ qui suppriment respectivement les périodes 6 (3ans) et 8 (4 ans puisqu'il y a 2 nombres par an). L'ensemble constitue un filtre à coefficients entiers.

On obtient ainsi la courbe 3 qui représente une variation undécennale



1- Moyennes annuelles des microséismes A
2- Variations interannuelles des nombres de Wolf R
3- Composante périodique undécennale de A
4- Amplitude de la période undécennale de la durée du jour ΔT (d'après Currie)
5- Amplitude 2a de la courbe 3

de forme inattendue puisque son amplitude diminue suivant la courbe 5 alors que l'activité solaire marque des valeurs exceptionnellement élevées.

Il est curieux que cette diminution d'amplitude se produise dans la même proportion (courbe 4) sur la composante undécennale de la rotation terrestre, d'après l'étude de la durée du jour faite par R.G.Currie, et présentée à l'Assemblée de Canberra. Or cette variation dépend du moment de rotation de la circulation générale de l'atmosphère et celle ci est corrélée, par l'intermédiaire des perturbations cycloniques, avec les microséismes, comme l'a montré notre collègue Zatopek.

Une période undécennale est donc bien réelle dans la météorologie terrestre. De récentes observations astrophysiques permettent d'en cerner le mécanisme: l'énergie du rayonnement solaire semble varier en raison inverse de la surface des taches. Cela apparaissait dans l'étude de Livingston sur la température du disque solaire, diminuant de 6° lors d'une augmentation de 25 unités de l'indice de Wolf. C'est devenu évident sur les mesures radiométriques présentées par R.C.Wilson, montrant une baisse du rayonnement total lors du passage sur le disque d'un important groupe de taches en avril, puis mai 1980.

Livingston lui même avait tout de suite compris l'importance de ce résultat pour la climatologie: les fluctuations solaires ont un effet purement thermique sur la basse atmosphère et il est vain d'en chercher l'intermédiaire dans les propriétés de la haute atmosphère, dont la densité est beaucoup trop faible pour avoir des répercussions sur les phénomènes troposphériques.

Mais comment expliquer la disproportion de l'effet terrestre lors des cycles solaires d'amplitude variable? De longues réflexions m'ont amené à proposer le mécanisme suivant:

Les perturbations atmosphériques étant alimentées par la différence de chaleur solaire reçue par unité de surface dans la zone tropicale et sur le reste du Globe, l'accroissement de cette différence lors de la diminution des taches entraîne la naissance de perturbations atmosphériques supplémentaires augmentant la moyenne des microséismes,mais dans le cas d'un maximum de taches très élevé, un déficit de chaleur s'accumule pendant plusieurs années, et le retour au rayonnement normal sans taches se fera avec une moindre différence d'énergie interne entre la zone chaude et la zone froide de la Terre, entraînant une diminution d'amplitude de l'effet terrestre.

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DIFFICULTIES OF THE SEISMIC RISK DETERMINATION IN HUNGARY

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The Carpathian Basin together with the Carpathian arched mountain structure can not be counted among strong earthquake zones, apart from the Vrancea territory in the SE corner of the Trans-Carpathian arc. For the seismic risk map construction statistical methods can not be applied for smaller tectonic units because of the scarcity of seismic events, therefore a greater attention has to be given to the study of geological properties.

Until now the maximum intensity map /Fig. 1/ was used to estimate the seismic nature of areas, when establishing factories and settlements, but this map reflected mainly the effects of a few strong earthquakes occurred in this century, thus it was worthless for the prediction of the probability of future earthquakes. Therefore the plotting of a new seismicity map became necessary.

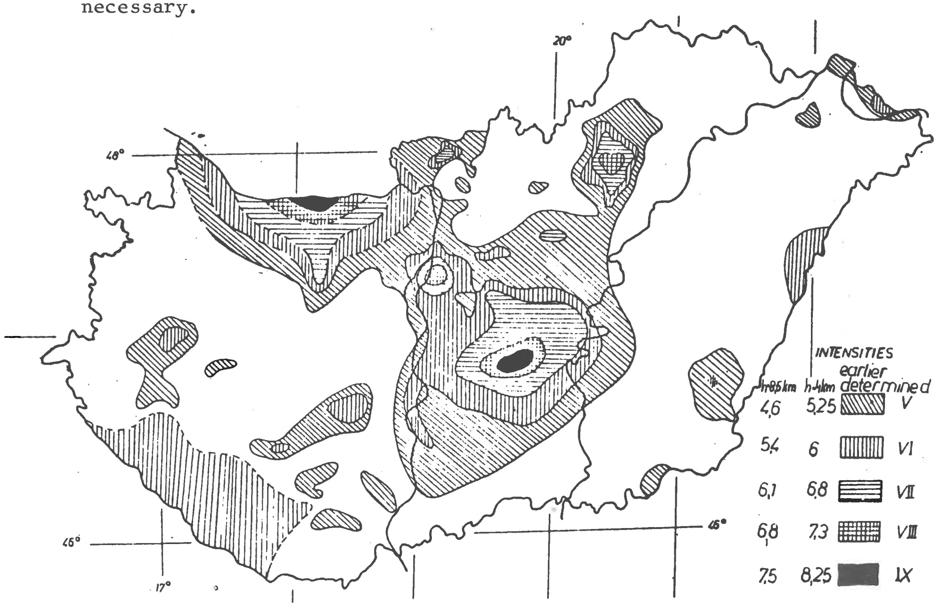

Fig. 1. - Maximum intensity map of Hungary. The Roman numbers mark the intensity values estimated earlier, the Arabic numerals mark the $I_0 = f(M_D)$ values projected on the Gutenberg-Richter curves

Fundamental requirements for the construction of seismic risk maps are

- the knowledge of correct intensity values,
- zone partitioning into homogeneous areas,
- determination of time stationariness of seismicity.

The first two points of these requirements were studied and the results of the investigations are shown in this paper.

First of all we have to pay attention to the correct reestimation of intensity values determined earlier. In spite of the low seismicity, ten earthquakes occurred in this century where many dwellings suffered heavy damages. Their maximum intensities were estimated as: $7^\circ \leq I_o \leq 9^\circ$. In the course of revision of these intensity values, we came to the idea that the intensities established earlier were in general overestimated. The bad conditions of the dwellings and the building materials of inferior quality were not yet taken into consideration, therefore especially the greater intensity values are exaggerated in the Réthly catalogue [1], where the historical earthquakes are enumerated from A.D. 455 till 1918.

We have to look for a possibility of real intensity estimation. This is feasible by means of the seismograms of the Hungarian earthquakes, since the instrumental observation has started in 1905 in Hungary. On the basis of these seismograms we can compare the function $M = f/I_o/$ obtained in Hungary with the equation computed by Gutenberg and Richter [2] in California.

More than sixty local earthquakes were selected where the epicentral distances were: $10\ km < \Delta < 300\ km$, and the time of first onset and the end of coda waves could be found in Bulletins. By means of the signal durations' method [3] the magnitudes were computed by the equation of

$$M_D = 2,12 \log t + 2,66 \qquad (1)$$

where t means the wave duration in minutes.

The M_D values were plotted against I_o epicentral intensities determined earlier partly by Réthly and predominantly by Csomor [4]. The coefficient of the equation

$$M_D = -0,0194\, I_o^2 + 0,706\, I_o + 0,369 \qquad (2)$$

were computed by least square's method and they can be seen together with curves of Gutenberg - Richter in Fig. 2.

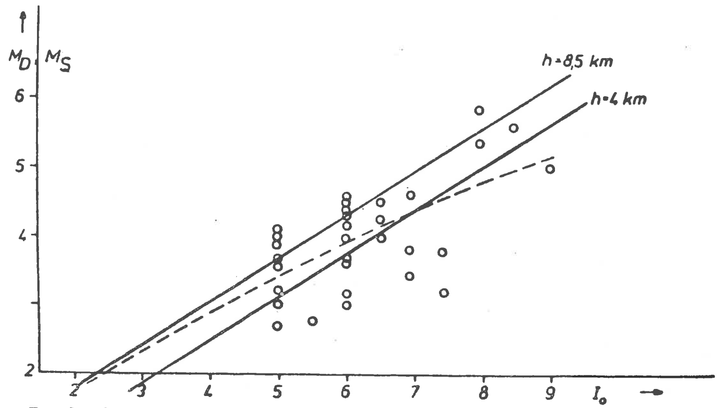

Fig. 2. - Magnitudes versus epicentral intensities. The intensities were estimated earlier and M_D values were computed by equation /1/. Pecked line belongs to equation /2/ unbroken lines represents the Gutenberg-Richter $I_o = f(M_S)$ function for two focal depths.

The Gutenberg - Richter equation was determined for depths of h = 4 and h = 8 km these being largely the most frequent focus depths in Hungary. In the following Table the new intensity values are shown obtained by projection of values of equation (2) on the Gutenberg - Richter curves.

Determined earlier I_o	$I_o = f/M/$ projected on the Gutenberg - Richter curves	
	h = 4 km	h = 8 km
2	3,2	2,3
3	3,75	2,8
4	4,6	3,75
5	5,5	4,6
6	6,3	5,4
7	7,0	6,1
8	7,7	6,8
9	8,35	7,5

The new intensity values are showing more reality. For instance for Kecskemét earthquake of 1911, where the epicentral intensity was 9° as determined earlier we obtained on the basis of signal duration a magnitude of $4,9 < M_D < 5,1$ and according to the Table, the new intensity value is only 7,5.

In order to apply the probability method we have to divide the Carpathian Basin into homogeneous tectonic areas, as it was mentioned above. That is the most important and at the same time, the most debatable point of this work.

In the Fig. 3 the recent vertical crustal movements can be seen. Neither the uplifted zones nor the subsided areas are in recognizable connection with the earthquakes. The maps showing the overall distribution of the volcanic rocks were also investigated /Fig. 4/.

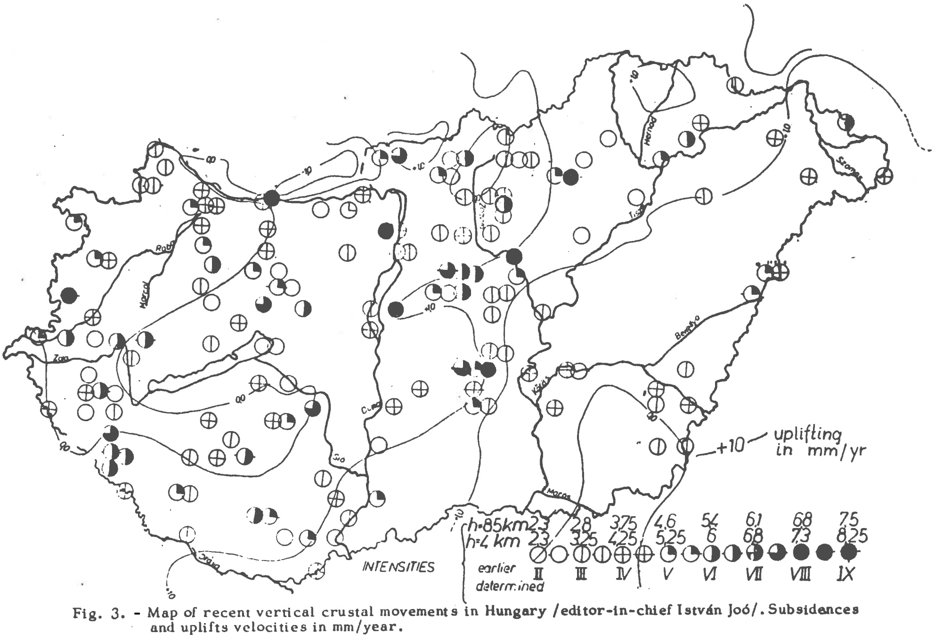

Fig. 3. - Map of recent vertical crustal movements in Hungary /editor-in-chief István Joó/. Subsidences and uplifts velocities in mm/year.

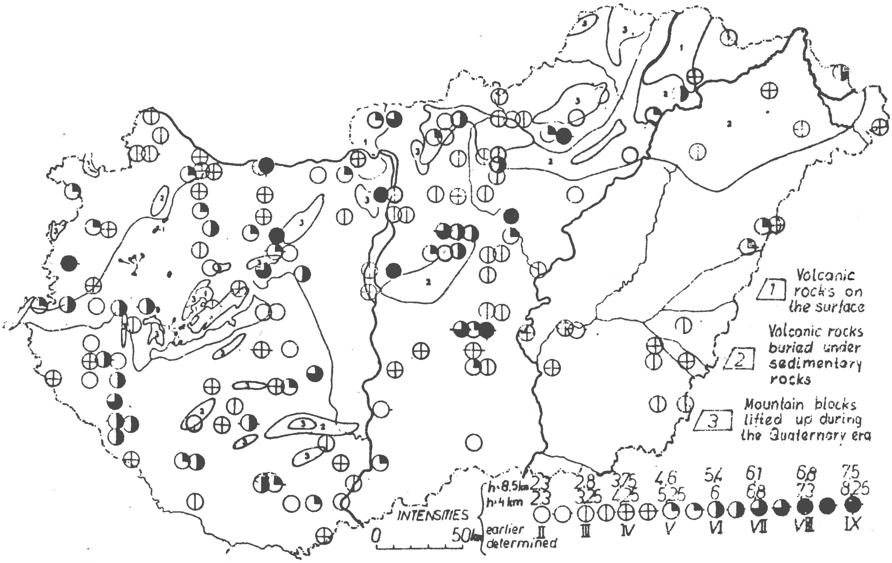

Fig. 4. - Distributions of volcanic rocks and epicenters. The different circles as the sites of epicenters are interpreted like Fig. 1.

The rocks are partly on the surface, partly they are covered by sedimentary rocks with a considerable thickness. There is no obvious correlation between recent earthquakes and the arrangement of the areas of volcanic rocks. That does not mean that there was no earthquake activity in the Miocene, but it can be stated that they are not in connection with the recent events.

In Fig. 5 the overall geological map shows on the one hand the deep Pliocene and Quaternary local basins, and on the other the mountain territories having been lifted during the Quaternary. It can be stated that most recent earthquakes were released on the borders of the mountain ranges and only a few of them occurred on the buried ranges. The body of the central massif consists mainly of Mesozoic rocks. They form the tectonic axis of the inner Carpathian belt. Their surroundings are tectonically still alive, and one can calculate with seismic risks here. Only the strong Kecskemét earthquakes was located far from the mountain peripheries; for this an other explanation can be offered. According to a few geologists the Vardar fault reaches the Carpathian Basin and crosses it in south-southeast - north-northwest direction. If this fault exists it could be the cause of the earthquakes of

Jászberény /1868, $I_o = 7$/ and Kecskemét /1911, $I_o = 7{,}5$/. This opinion can be supported by the fact that the Danube river-bed passed nearly along the same line in the early Quaternary.

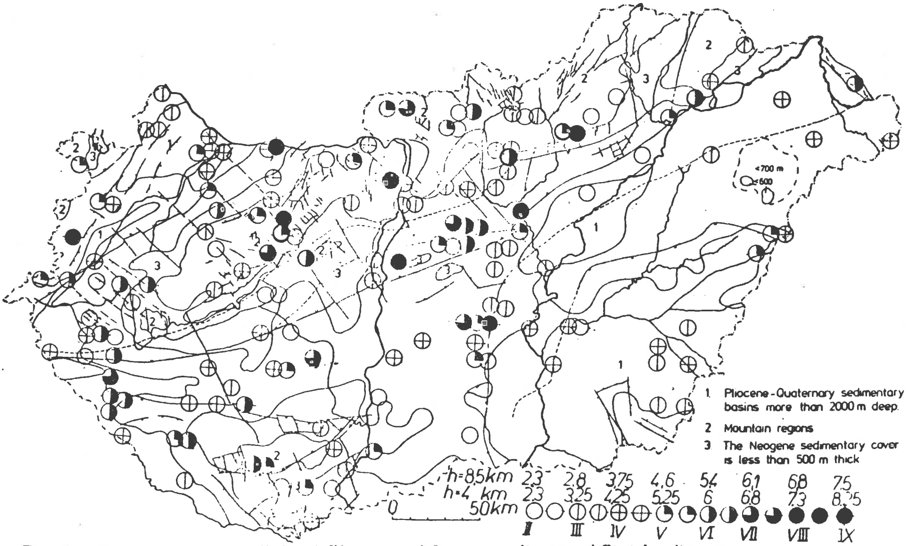

Fig. 5. - Deep young basins filled with Pliocene and Quaternary limnic and fluvial sediments. The marks of epicenters are interpreted like Fig. 1.

It should be noted that the areas of the big and deep Pliocene and Quaternary basins are poor in earthquakes, in spite that they are actually the most mobile tectonic bodies. Here presumably the compaction of vast unconsolidated sediments causes a few but slight earthquake movements.

According to the tectonic map of the Carpathian Basin compiled by Balogh and Körössy /Fig. 6/ this area can be devided into seven structural units. But on the one hand these units do not produce a sufficient quantity of events for statistical computations, and on the other hand some units show similar tectonic properties, therefore a merging of the units seemed to be logical. Thus the units I. II., the western part of III. and unit IV. could be reduced into one, because of their tectonic conformity. The other unit was the eastern part of unit III., as the supposed Vardar rift valley. These two zones partly overlap each other. Finally, units V. VI. VII. were merged into one; the earthquakes on this area are supposed as brought about by compaction of unconsolidated strata.

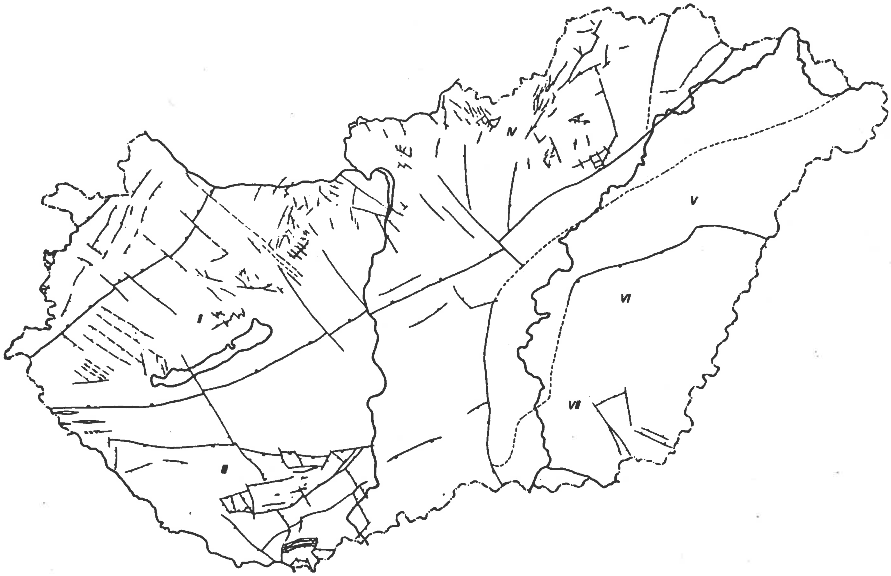

Fig. 6.- Sketch of tectonic map of Hungary compiled by K.Balogh and L.Kőrössy. Roman numbers mark the different tectonic units.

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THE ROLE OF BOUNDARY CONDITIONS IN THE ESTIMATE OF EARTHQUAKE RECURRENCE TIMES

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1. Introduction

It is well known that fault regions are intensively fractured. Faulting appears to occur at all scales: faults vary in length from thousands of kilometres to cristalline dimensions and intersect one another in a complex pattern (King, 1978). This suggests that modelling the fault zone as a homogeneous elastic medium with a single fault surface in it may be inadequate, at least for long-term deformation. In particular, the presence of a large number of secondary faults and smaller fractures, on which creep occurs in response to applied stresses, makes the crust effectively more compliant. The change in compliance is gradual and the overall effect may not be distinguishable from viscoelastic relaxation (Mavko, 1981). It seems therefore meaningful to introduce an effective viscosity in describing the rheology of highly fractured zones. Budianski and Amazigo (1976) examined the interaction between slip on a long strike-slip fault and lithospheric creep, by modelling the lithosphere as a Maxwell viscoelastic plate. By imposing on the plate a uniform shear stress applied at a very large distance, laterally with respect to the fault, they obtained a solution for the periodic occurrence of earthquakes on the fault. A relation for the recurrence time of earthquakes was given. On the basis of this model, they inferred an effective viscosity of the order of 10^{21} P for the San Andreas fault region. Burridge (1977) generalized Budianski and Amazigo's (1976) model by representing the lithosphere as a half-space with the rheology of a general linear viscoelastic solid and introducing a more realistic fracture criterion on the fault. When specialized to a Maxwell solid, his result for the earthquake recurrence time does not differ appreciably, however, from the relation obtained by Budianski and Amazigo (1976).

Both these models impose boundary conditions on stress. However, the state of stress in the lithosphere is poorly known (see e.g. Hanks, 1977). In connection with the earthquake occurrence, we often have information on the stress drop, but not on the absolute values of stress before and after the seismic event. Moreover, the stress field is very sensitive to local inhomogeneities. On the contrary, we have a fairly detailed knowledge of the strain rate field at the Earth's surface. Both geodetic and paleomagnetic data provide a measure of this field. The long-term displacement at depth must be the same as at the surface for plate motions to be accommodated at depth; this displacement takes place mostly aseismically at depth (Davies and Brune, 1971). In modelling the ground deformation along a plate margin, it might then be more appropriate to impose boundary conditions on strain rate, rather than on stress. This may drastically alter the estimate of the recurrence time of great earthquakes.

2. The model

We model the fault region as a Maxwell viscoelastic half-space characterized by a shear modulus μ and a viscosity η. A long, vertical strike-slip fault lies on the plane $x_2=0$ and extends from the Earth's surface ($x_3=0$) to depth $x_3=d$. The model is two-dimensional, all quantities being uniform in the x_1 direction (Fig. 1). Moreover, only the u_1 component of the displacement field is non-vanishing. Accordingly

$$\varepsilon_{21} = \frac{1}{2}\, \partial u_1 / \partial x_2 \tag{1}$$

is the relevant shear strain component in our model. The corresponding stress component is

$$\sigma_{21} = 2\mu \varepsilon_{21} \tag{2}$$

The constitutive equation for a Maxwell solid is

$$\dot{\sigma}_{21}/\mu + \sigma_{21}/\eta = 2\dot{\varepsilon}_{21} \tag{3}$$

where dots denote differentiation with respect to time. Following Budianski and Amazigo (1976), we suppose that slip on the fault occurs when the applied shear stress reaches a statical friction resistance σ_S and that, due to this slip, stress on the fault drops to a dynamical friction resistance σ_D. Free-surface boundary conditions are assumed at the Earth's surface (x_3=0):

$$ \tag{4} $$

We assume that the fault region is deformed by a uniform, constant strain rate field:

$$\dot{\varepsilon}_{21}(x_2, x_3) = K \tag{5}$$

as sketched in Fig. 1. K is half the velocity gradient in the x_2 direction. If we assume that the last earthquake occurred on the fault at t=0, the displacement field at a later time t is given by the displacement of a viscous medium plus an arbitrary initial displacement:

$$u_1(x_2, x_3; t) = 2K x_2 t + u_1(x_2, x_3; 0+) \tag{6}$$

From (1) and (2) it follows that

$$\dot{\sigma}_{21}/\mu + \sigma_{21}/\eta = 2K \tag{7}$$

The solution is

$$\sigma_{21}(x_2, x_3; t) = 2K\eta(1 - e^{-t/\tau}) + \sigma_{21}(x_2, x_3; 0+)\, e^{-t/\tau} \tag{8}$$

where

$$\tau = \eta/\mu \tag{9}$$

is the Maxwell relaxation time. On the fault surface, $0 \leq x_3 \leq d$,

$$\sigma_{21}(0, x_3; t) = 2K\eta(1 - e^{-t/\tau}) + \sigma_D e^{-t/\tau} \tag{10}$$

This stress is plotted in Fig. 2 for various times. The shear stress $\sigma_{21}(0,x_3;t)$ on the fault surface remains uniform, so that the next earthquake will occur at time t=T, when σ_{21} reaches again the value σ_S:

$$\sigma_{21}(0, x_3; T) = \sigma_S \tag{11}$$

From (10) and (11) we obtain the relation

$$T = \tau \log\left[(2K\eta - \sigma_D)/(2K\eta - \sigma_S)\right] \tag{12}$$

for the recurrence time of great earthquakes on the fault. The recurrence time T as a function of the effective viscosity η is plotted in Fig. 3. At time t=T, we have a uniform stress drop $\Delta\sigma$ on the fault,

$$\Delta\sigma = \sigma_S - \sigma_D \tag{13}$$

and a displacement discontinuity

$$\Delta u_1(x_3) = 2\Delta\sigma(d^2 - x_3^2)^{1/2}/\mu \tag{14}$$

If the slipped fault has horizontal length L ($L \gg d$), this gives a seismic moment

$$M = \pi L d^2 \Delta\sigma / 2 \qquad (15)$$

As deduced from Eq. (12) and Fig. 3, the earthquake recurrence time T has a lower limit

$$T_{min} = \Delta\sigma / (2K\mu) \qquad (16)$$

which is proportional to the stress drop $\Delta\sigma$. There is also a lower limit for the effective viscosity:

$$\eta_{min} = \sigma_S / (2K) \qquad (17)$$

For most viscosity values, the recurrence time is very close to its minimum value T_{min}. It is substantially higher only when the effective viscosity is close to its minimum value η_{min}. As can be seen from Fig. 3 , T tends to infinity as η approaches η_{min}. The physical meaning of the existence of a lower limit for η is that for too low a viscosity, stress relaxation is too fast and the shear stress on the fault surface can never reach the critical value σ_S required for slipping. This is evident from Eq.(10), where the maximum shear stress which can be attained on the fault surface is $2K\eta$. It is therefore clear why η_{min} depends on σ_S. We must have $2K\eta > \sigma_S$ in order that the earthquake 'engine' may work.

Had we assumed a boundary condition of uniform stress σ_A applied at infinity,

$$\sigma_{21}(x_2, x_3) = \sigma_A \qquad (18)$$

the displacement field would be

$$\text{[illegible]} \qquad (19)$$

By comparison with Eq. (6), the solution to this problem is simply obtained by substituting σ_A/η to 2K in all equations. In particular, the earthquake recurrence time would be

$$\text{[illegible]} \qquad (20)$$

which is the relation obtained by Budianski and Amazigo (1976). In this case T depends linearly on η.

3. Discussion and conclusions

We have obtained a relation for the recurrence time T of great earthquakes on the fault, by imposing boundary conditions of assigned velocity or velocity gradient. These relation, Eq.(12), is different from the one obtained by

Budianski and Amazigo (1976), Eq.(20), who imposed stress boundary conditions, so that a markedly different behaviour of T as a function of η is obtained (Fig. 3). We apply now this model to the Northern 'locked' segment of the San Andreas fault and try a numerical estimate of some of the quantities involved in the model. We use throughout d=10 km for the maximum fault depth (see e.g. Barker, 1976) and $\mu = 3x10^{11}$ dyne/cm^2 for the shear modulus.

Savage and Burford (1973) inferred a relative plate velocity across the San Andreas fault of about 3 cm/yr from geodetic measurements carried out at a maximum distance $|x_2| \simeq 50$ km from the fault trace. This gives a strain rate $K \simeq 3x10^{-7}yr^{-1}$ (see also Thatcher, 1975b). From Eq. (14), a stress drop $\Delta\sigma \simeq 60$ bar corresponds to a surface slip $\Delta u(0) \simeq 4m$, which is the average value observed after the 1906 San Francisco earthquake (Thatcher, 1975a). From Eq.(15), with L=500 km, a seismic moment $M=4x10^{27}$ dyne cm is obtained, which agrees with the one determined from long-period surface wave amplitudes (Thatcher, 1975a). With the same stress drop, we obtain from Eq.(16) a minimum recurrence time $T_{min} \simeq 330$ yr. Smaller earthquakes would have comparatively shorter recurrence times. We note that, if we take $\sigma_S \simeq 100$bar as the order of magnitude of the critical stress, we obtain $\eta_{min} \simeq 5x10^{21}$P from Eq.(17), which is of the same order of magnitude as the effective viscosity obtained by Budianski and Amazigo (1976). In our case this is only the minimum value and all higher values are admissible.

The estimate obtained for the minimum earthquake recurrence time is considerably larger than the value $T \simeq 100$yr which is commonly quoted for the San Andreas fault. In the framework of our model, with assigned strain-rate boundary conditions, if the strain accumulation process is uniform in time, the only possibility that great earthquakes have shorter recurrence times is to have a somewhat larger strain rate K. It seems however that stress accumulation is non--uniform in time. During the 50 years preceding the 1906 San Francisco earthquake, the strain accumulation rate measured at the Earth's surface was considerably higher than nowadays, ranging from 4 to $9x10^{-7}$ yr^{-1} (Thatcher, 1975a). As to the origin of the frequently quoted 100-year recurrence period for great earthquakes on the San Andreas fault, it seems to come from Reid's (1910) inferences based on measurements taken before the 1906 San Francisco earthquake. As pointed out by Thatcher (1975a), this is correct only if strain accumulated uniformly in time: in fact, from Eq.(16), if $K=9x10^{-7}$ yr^{-1} and $\Delta\sigma = 60$ bar, we get $T_{min} \simeq 110$ yr. Since shear straining was considerably greater before the 1906 earthquake than after it, any recurrence time estimated on the basis of pre-earthquake data is likely to be inaccurate. If the present value of the strain rate is representative of the average inter-seismic value, the acceleration observed during the 50 years preceding the 1906 San Francisco earthquake might be due, among other possibilities, to an increasing rate of aseismic slippage at depth or to a gradual extension of the aseismic slippage zone to shallower depths (Bonafede and Dragoni, 1982). A possibility is that a similar evolution of the fault region may repeat in the future: in this case, the next large earthquake on the Northern 'locked' segment of the San Andreas fault might be announced by an increase in strain rate. The preseismic acceleration in straining would have the effect of decreasing the earthquake recurrence time with respect to the values found in the present work, still keeping it above the 100-years estimate.

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Figure captions

Fig. 1 - Uniform strain rate model for the fault region. The dashed contours denote the unstrained state, the arrows denote the displacement field.

Fig. 2 - Shear stress on the fault surface as a function of depth x_3, for various values of time in units of the recurrence period T. The graph is drawn for $\sigma_D = \sigma_S/4$ and $T = \tau/2$.

Fig. 3 - The recurrence time T of great earthquakes as a function of effective viscosity η, according to our model. The graph is drawn for $\sigma_D = \sigma_S/4$.

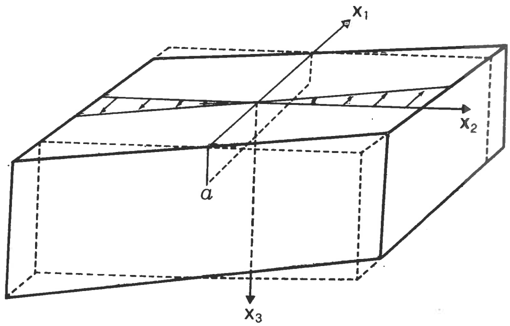

Fig. 1

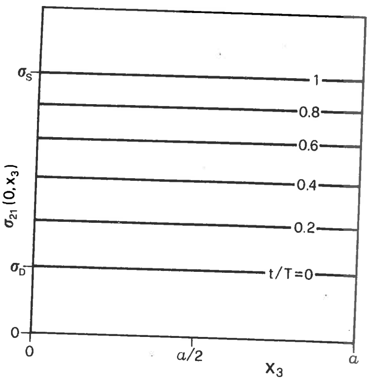

Fig. 2

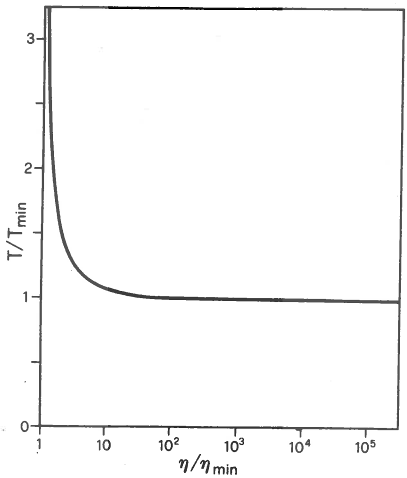

Fig. 3

TIME-DEPENDENT CHANGE IN THE MOMENT OF INERTIA DUE TO FAULTING IN A TWO-LAYER VISCOELASTIC PLANET

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1. Introduction

The change in the moment of inertia of the Earth due to earthquakes has been studied by several authors in the case of an elastic planet (Mansinha and Smylie, 1967; Smylie and Mansinha, 1971; Dahlen, 1971, 1973; O'Connell and Dziewonski, 1976). These efforts were mainly directed to ascertain whether this mechanism is capable of exciting the Earth's free precession, or Chandler wobble (Munk and Mac Donald, 1960). However, the results have been unsatisfactory so far. In the present work we shall study the role played in this problem by a viscoelastic structure of the Earth's mantle in the presence of an elastic lithosphere. As a result, we obtain the temporal evolution of the inertia tensor as a consequence of earthquake faulting.

2. The change in the moment of inertia

Calculation of the change ΔI_{ij} in the moment of inertia of the Earth would require in principle the knowledge of the entire displacement field due to faulting. A simple way of obtaining ΔI_{ij} has been found by Rice and Chinnery (1972). The moment of inertia of a sphere about an axis having the orientation of a unit vector $\hat{n}$ is

$$I^{(\hat{n})} = \int_M X^2 \, dm \tag{1}$$

where X is the perpendicular distance from the axis to the mass element dm and M is the total mass. When the sphere is subjected to the displacement field $\underline{U}(\underline{r})$ due to the presence of a dislocation, the change in the moment of inertia is, to first order,

$$\Delta I^{(\hat{n})} = 2\int_M X\, U_X\, dm \qquad (2)$$

where U_X is the displacement component in the radially outward direction from the axis. One may note that eq. (2) is nothing but twice the work done by a centrifugal body force $\omega^2 X$ per unit mass on the displacement $\underline{U}$, when $\underline{\omega} = \hat{\underline{n}}$. Since the centrifugal force is derivable from a potential field which is formed by spherical harmonics of degrees zero and two, the result obtained means that only the terms of degrees zero and two in the displacement field produced by faulting contribute to a change in the moment of inertia, as should be expected.

We now apply Betti's theorem (Love, 1927) to an elastic sphere. This theorem yields a relationship between two different configurations of the same elastic body. Consider the following configurations:

(1) A sphere has a shear dislocation $\Delta\underline{u}$ across an internal surface Σ. In this situation we have no body force, a displacement field U_i and a stress field Σ_{ij}, associated with the dislocation.

(2) A sphere is rotating with angular velocity ω around an axis directed as $\hat{\underline{n}}$: in this case there is a centrifugal body force F_i per unit mass, a displacement field u_i and a stress field σ_{ij}.

Applying Betti's theorem to these two configurations we get the following relationship

$$\int_M F_i U_i\, dm = \int_\Sigma \nu_j \sigma_{jk} s_k \Delta u\, dS \qquad (3)$$

where $\hat{\underline{\nu}} = \hat{\underline{\nu}}^- = -\hat{\underline{\nu}}^+$, $\hat{\underline{\nu}}^+$ and $\hat{\underline{\nu}}^-$ being the unit outward normals to the sides Σ^+ and Σ^- respectively of the fault surface Σ and $\hat{\underline{s}}$ is a unit vector in the slip direction at every point of Σ:

$$\Delta\underline{u} = \Delta u\, \hat{\underline{s}} \qquad (4)$$

We see that eq. (3) represents just the work done by the centrifugal body force $\underline{F}$ on the displacement $\underline{U}$ due to faulting, which is required from eq. (2) to obtain the change in the moment of inertia. We have then

$$\Delta I^{(\hat{n})} = 2\int_\Sigma \tau^{(\hat{n})} \Delta u\, dS \qquad (5)$$

where

$$\tau^{(\hat{n})} = \nu_j \sigma_{jk} s_k \qquad (6)$$

is the shear stress induced on the (unslipped) fault surface by the centrifugal force $\underline{F}$ (case 2 above). It can be shown (Rice and Chinnery, 1972) that the change in a general component I_{ij} of the inertia tensor is given by

$$\Delta I_{ij} = 2 \int_{\Sigma} \tau^{(ij)} \Delta u \, dS \qquad (7)$$

where $\tau^{(ij)}$ is defined in such a way that

$$\tau^{(\hat{n})} = n_i n_j \tau^{(ij)} \qquad (8)$$

Since $\tau^{(ij)}(\underline{r})$ will be a smooth function of position over size scales much larger than typical fault dimensions, one can approximate eq. (7) by

$$\Delta I_{ij} = 2 \tau^{(ij)} \Delta u \, \Sigma \qquad (9)$$

where $\tau^{(ij)}$ is evaluated at a representative point of Σ.

3. The model

We consider a two-layer, spherical elastic Earth model. The inner layer, the mantle, has radius r_1, density ρ_1 and rigidity μ_1, while the outer layer, the lithosphere, has an outer radius r_2, density ρ_2 and rigidity μ_2 (Fig. 1). The displacement field $\underline{u}(\underline{r})$ within the elastic sphere can be written in the form (Love, 1909):

$$\underline{u}(\underline{r}) = \sum_{\ell=-\infty}^{\infty} \left[\underline{u}_\ell(\underline{r}) - (r^2/2\ell) \nabla \psi_\ell(\underline{r}) \right] \qquad (10)$$

where $\underline{u}_\ell$ is a set of three spherical solid harmonics of degree ℓ and $\psi_\ell(\underline{r})$ is another representation of the spherical solid harmonic, defined as

$$\psi_\ell(\underline{r}) = \nabla \cdot \underline{u}_{\ell+1}(\underline{r}) \qquad (11)$$

We also introduce a spherical solid harmonic $\varphi_{-\ell-2}(\underline{r})$ of degree $-\ell-2$

$$\varphi_{-\ell-2}(\underline{r}) = \nabla \cdot \left[\underline{u}_\ell(\underline{r}) / r^{2\ell+1} \right] \qquad (12)$$

The body force to which the sphere is subjected is the centrifugal force due to steady rotation around the x_3 axis, as shown in Fig. 1. The centrifugal potential

$$W(\underline{r}) = \frac{1}{2} \omega^2 (x_1^2 + x_2^2) \qquad (13)$$

can be expressed us a sum of a degree-zero spherical solid harmonic W_0 plus a degree-two spherical solid harmonic W_2:

$$W_0(r) = \frac{1}{3} \omega^2 r^2 \qquad (14)$$

$$W_2(\underline{r}) = \frac{1}{6}\omega^2(x_1^2+x_2^2-2x_3^2) \qquad (15)$$

where $r^2=x_1^2+x_2^2+x_3^2$ and ω is the angular frequency of rotation. W_0 gives a purely radial force field, so that it does not produce any displacement in an incompressible sphere. Thus we have to compute only the displacement due to W_2. It can be seen that, if the applied potential is a spherical harmonic of degree two, only six harmonic functions appear in the expressions for displacement and stress. By means of eq. (10) and the corresponding expression for stress, we can write down the boundary conditions to be satisfied at the interface between the two layers (the surface $r=r_1$) and at the Earth's surface ($r=r_2$). We impose boundary conditions of continuity of displacement and traction across the lithosphere-mantle interface and stress-free boundary conditions at the surface. These conditions can be reduced to an algebraic system of six equations in six unknowns. According to eq. (10), the displacement field in the lithosphere is found to be

$$\underline{u}(\underline{r}) = f(r)\,\nabla W_2 + g(r)\,W_2\,\underline{r} \qquad (16)$$

where f and g are functions of r. The shear stress $\sigma_{ij}(\underline{r})$ is then given by Hooke's law:

$$\sigma_{ij}(\underline{r}) = \mu_2\,(u_{i,j}+u_{j,i})\ , \qquad r_1 \le r \le r_2 \qquad (17)$$

From eq. (16)

$$\sigma_{ij}(\underline{r}) = \mu_2\,[\,f_{,j}W_{2,j} + f\,W_{2,ij} + g_{,j}W_2 x_i + g\,W_{2,j}x_i + g\,W_2\delta_{ij} + (i\leftrightarrow j)\,] \qquad (18)$$

where $(i\leftrightarrow j)$ represents the same expression as before with the indices i and j interchanged. Let us now consider a strike-slip fault across which a dislocation $\Delta\underline{u}$ is imposed. Here we denote a representative point of the fault surface Σ by $\underline{r}'$. The component of the shear stress projected upon Σ in the slip direction $\hat{\underline{s}}$ is given by eq.(6) to be:

$$\tau^{(\hat{n})}(\underline{r}') = \mu_2\,f(r')\,W_{2,ij}\,(\nu_i s_j + \nu_j s_i) \qquad (19)$$

The expression of $\tau^{(k\ell)}$ (eq.8) which will be used in Rice and Chinnery's formula becomes

$$\tau^{(k\ell)}(r') = -\mu_2 f(r')\,(\nu_k s_\ell + \nu_\ell s_k)\ . \qquad (20)$$

For shallow earthquakes, one can make the approximation $r' \simeq r_2$ (the Earth's radius). The rheology of the mantle is modelled as a Maxwell viscoelastic solid with shear modulus μ_1 and viscosity η. This rheology model behaves initially as an elastic solid and becomes a Newtonian fluid after a characteristic time $\tau_M = \eta/\mu_1$ (the Maxwell time). The temporal change in the moment of inertia can be readily obtained from the elastic increment, eq. (9), by using the correspondence principle for linear viscoelastic materials (see e.g. Fung, 1965). In our case, this is equivalent to the transformation

$$\mu_1 \rightarrow \mu_1(s) = \mu_1 \eta s / (\eta s + \mu_1) \qquad (21)$$

where s is the complex Laplace variable. A Heaviside function $H(t)$ is introduced to describe the jump discontinuity of the displacement across the fault

$$\Delta u(t) = \Delta u \; H(t) \qquad (22)$$

From substituting eq. (22) into (9) and using expressions from eqs. (20) and (21), the change $\Delta\tilde{I}_{ij}(s)$ of the inertia tensor in the Laplace transform domain is obtained. $\Delta\tilde{I}_{ij}(s)$ is characterized by three poles: a pole at x=0 which is associated with the permanent deformation in the final state and two poles s_1 and s_2 which are designated respectively to be the mantle and lithospheric poles. The relaxation time τ_i of each mode is defined to be $-1/s_i$ (i = 1,2). In Fig. 2 , for a mantle viscosity of 10^{22}P, we display the relaxation times of the two modes as a function of the shell thickness $R = r_1/r_2$. As $R \rightarrow 1$, the relaxation time of the lithospheric mode approaches infinity, whereas that of the mantle mode approaches a value associated with a homogeneous viscoelastic sphere. For a thick elastic shell (or $R \rightarrow 0$) the relaxation time of the lithospheric mode approaches a constant value , whereas the mantle mode relaxes with a timescale identical to the Mawxell time τ_M . The Earth, whose lithospheric thickness is around 100 km, lies in the thin-shell regime with $R \simeq 0.98$. By taking the inverse Laplace transform of $\Delta\tilde{I}_{ij}(s)$ we obtain the following expression for the temporal evolution of the change in the moment of inertia

$$\Delta I_{ij}(t) = T_{ij} \, \Delta u \, \Sigma \, (C_1 e^{-t/\tau_1} + C_2 e^{-t/\tau_2} + C_3) \qquad (21)$$

where C_1, C_2 and C_3 are coefficients independent of time and T_{ij} is a second order tensor describing the geometry of faulting.

4. Conclusions

It has been suggested (Slade et al., 1979) that viscoelastic flow in the mantle induced by earthquakes might provide an additional mechanism sufficient to maintain the excitation of the Chandler wobble. For a homogeneous viscoelastic Earth with Maxwell rheology, the initial excitation arising from the elastic contribution vanishes as the planet tends to a fluid limit (Yuen and Peltier, 1982). This is not the case, however, for a two-layer model with elastic lithosphere. The results are shown in Fig. 3 for a range of shell thicknesses. The presence of the lithosphere affects the dynamics quite differently from that of a homogeneous model. For the thick-shell situation ($R \approx 0.5$), the viscoelastic solutions do not differ greatly from their elastic counterpart in that the thick elastic shell prevents any surface deformation from transient creep to take place. However, as the thickness of the elastic shell is reduced, the stress exerted by the viscoelastic flow upon the lithosphere gives rise to a further increase in the change of the moment of inertia. For a shell thickness similar to that of the Earth ($R \simeq 0.98$) an enhancement of a factor around four is obtained. Of course, in the limit of an extremely thin lithosphere ($R \to 1$), some other physical processes, such as rupturing, would occur.

The time scales associated with the rapid changes in the moment of inertia are of the order of 10 Maxwell times. Since an oscillation can only be excited substantially by functions whose time scales are comparable to the period of the oscillation itself, an upper bound of 5×10^{18}P is required for mantle viscosity in order for the Chandler wobble to be enhanced by viscoelasticity. However, these values for the mean mantle viscosity are about four orders of magnitude lower than that inferred from postglacial rebound (e.g. Cathles, 1975). Hence, we would not expect the excitation of the Chandler wobble to be enhanced for values of the long-term viscosity derived from post-glacial rebound.

Acknowledgments

One of the authors (M.D.) has performed this work while he was on leave from the Istituto di Geofisica, Università di Bologna, Italy, with a fellowship of the Consiglio Nazionale delle Ricerche.

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<u>Figure captions</u>

Fig. 1 - The Earth model employed in this paper: r_1, ρ_1, μ_1 are the mantle radius, density and rigidity, respectively; r_2, ρ_2, μ_2 are the lithosphere outer radius, density and rigidity, respectively.

Fig. 2 - Viscoelastic relaxation times as functions of the ratio $R = r_1/r_2$.

Fig. 3 - Temporal changes in the scalar moment of inertia for two-layer Earth models with a Maxwell-viscoelastic mantle and an elastic lithosphere. Different curves refer to different values of $R = r_1/r_2$. $\mu_1 = 1.45 \times 10^{12}$ dyne/cm^2 $\mu_2 = 2.82 \times 10^{11}$ dyne/cm^2, $\rho_2 = 2.69$ g/cm^3, while ρ_1 is chosen so that the Earth model has always a mass $M = 5.976 \times 10^{27}$ g.

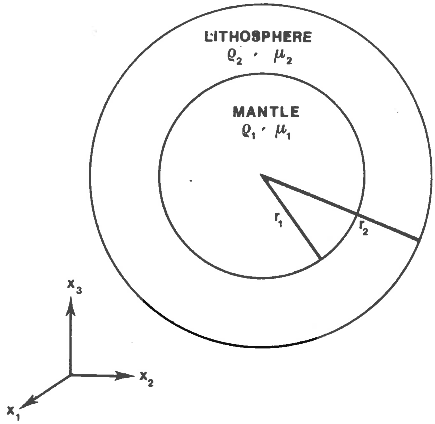
LITHOSPHERE
ϱ_2 , μ_2
MANTLE
ϱ_1 , μ_1
r_1
r_2
x_3
x_2
x_1

Fig. 1

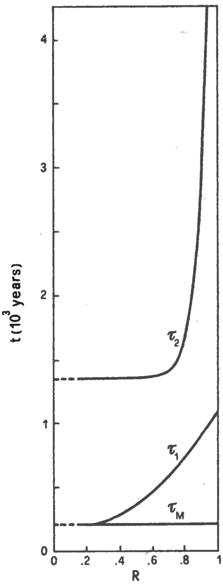
t (10^3 years)
4
3
2
1
0
τ_2
τ_1
τ_M
0
.2
.4
.6
.8
1
R

Fig. 2

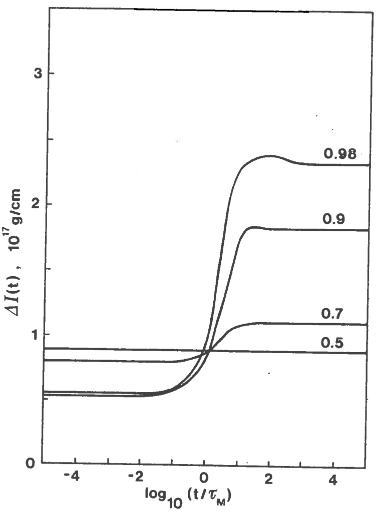

Fig. 3

GEODYNAMIC/VISCO-ELASTIC MODELS AND NEW INTERPRETATION TRENDS FOR GEOPHYSICAL AND GEOLOGICAL EVIDENCES ALONG APENNINES AREAS (EASTERN ITALIAN PENINSULA)

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FOREWORD

The present research trend had been envisaged by improving a tentative visco-elastic model, Nadai 1963, Finzi-Contini 1977, trying to describe quantitatively certain patterns of the gravimetrical field along Italian peninsula, see also Mongelli et al. 1975, Finzi-Contini 1981. Actually, a seismological aspect related to Italian areas connected with a typical "shallow seismicity" severely affecting that region - as it will be discussed later - is the very basic research motivation suggesting such an investigation, Cimino e Finzi-Contini, 1979.

As main border conditions for the mechanical problems discussed in this work, those ones examined by Scandone et al 1974, Scandone 1979 should be considered essential, as they deal with the opening of the Tyrrhenian Sea and its consequences on the rotation of the so-called palaeogenic nucleus, anti-clockwise rotating from Miocene possibly until present. According to these hypotheses, Italian peninsula can be considered a portion of a larger geo-structure both forced to rotate and simultaneously stressed by an action attributable to the African plate. A consistent component of this action is assumed to be parallel to the main geographical trend of the studied peninsula during the aforesaid rotation, despite other deformations experienced by local structures.

GEOPHYSICAL AND GEOTECTONICAL EVIDENCES

In the considered area, quite a good amount of geo-data have been recently accumulated, see Fig. 1 also for the following. In particular, reference should be made to the Moho's isobates map as well as to a selection of seismic events for the time interval quoted in the figure, their magnitude being $\geqslant 3.0$; in addition to that, one can see there a simplified map related to the altitude of the Apennine range, together with the output of the mentioned visco-elastic model for time T = 10 Myrs, as obtained in the previously quoted work, just for comparison. The same figure shows also the patterns of the Pliocenic faulting systems for the North-Western side of the

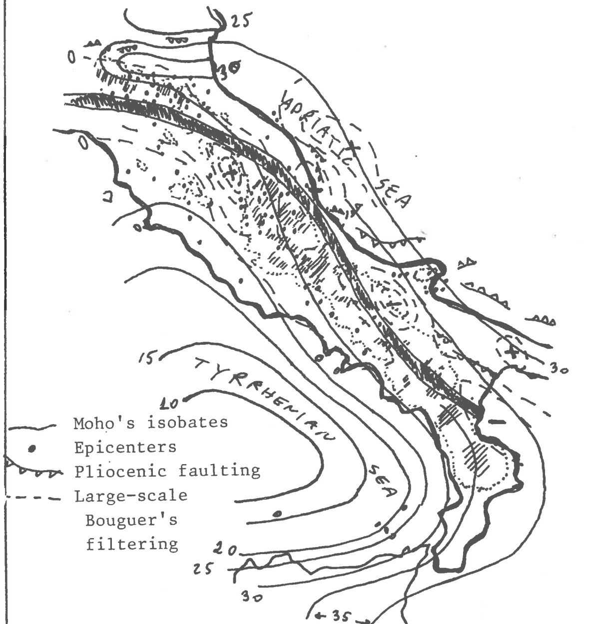


Fig. 1 - A selection of evidences collected for the considered areas.
The dotted lines contour areas having altitude higher that 500 m a.s.l.; dashed zones show mountains higher than 1000 m a.s.l..
The thick line schematizes the visco-elastic model output for T = 10 Myrs, Finzi-Contini 1977.

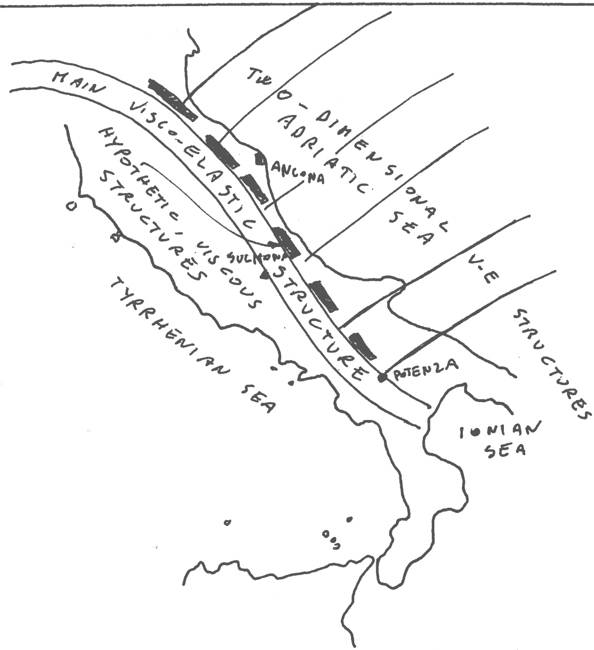


Fig. 2 - A schematic representation of the visco-elastic/viscous model structures adopted to simulate a number of mechanical features of the studied region.
See the text for detailed references and the assembling philosophy.

Apennines. For sake of completness, a simplified version of the regional gravimetrical map obtained by Corrado & Rapolla 1977 is superimposed to the other collected pieces of information.

BASIC VISCO-ELASTIC/VISCOUS MODELS FOR THE ITALIAN AREAS

Besides the quoted visco-elastic model (see Fig. 2, also for the following), which is able to qualitatively account for the known displacement between Apennines relief and negative gravimetrical anomaly along Italian peninsula, a number of models have been elaborated in order to better picture different aspects of this problems. In particular - also according to a preliminary work dealing with parallelepiped-shaped, viscous masses supposed to be squeezed by visco-elastic structures, Finzi-Contini 1982 - a qualitative interpretation approach suggested the presence of a system of three deep sources of gravimetrical anomalies in correspondence with the Eastern side of the Apennine range, Finzi-Contini 1981, Finzi-Contini & Lipparini 1982. In other words, by assembling both visco-elastic and purely viscous model structures such a situation has been envisaged, that mechanically accounts for a number of geodynamic and geophysical evidences: the acceptable quality of the gravimetrical check of the simulated behaviour shown by the viscous elements of the assembled model seems to be quite a positive result provided by the adopted approach.

More in detail, this interpretation have been carried out by deducing a proper Bouguer anomaly map from an existing regional one, Corrado & Rapolla 1977, as in the following section it will be discussed.

GRAVIMETRICAL FIELD AND SUGGESTED MODELS

The gravimetrical patterns of the investigated area, with particular emphasis on the Adriatic side of Italian peninsula, have been investigated in detail in order to connect possible symptoms of buried, sub-regional masses with the suggestions given by the models assembling Visco-Elastic and Viscous Structures (V-E/VS). The outputs of this investigation are drawn in Fig.3, where both regional and sub-regional gravimetrical fields can be compared.

It can be seen that an elongated trough, suggested by a regional field of negative anomalies, broadly speaking running in the N-W/S-E direction, affects the Adriatic margin of Italian peninsula, while three relative maxima - all of them characterized by sub-regional positive anomalies = mark as many other areas, namely the Marche, the Abruzzi/Molise and the Basilicata as well:

their respective tops are approximately centered on the towns of Ancona, Sulmona and Potenza, at least according to the elaborations, which have been carried out by using the mentioned map. These three families of sub-regional anomalies show patterns, which can be considered oval, if one ignores their minor perturbations. This means that also a first approximation interpretation scheme should avoid any two-dimensional model structures. On the other side, these closed, oval-like gravimetrical patterns still preserve elongated trends along the same direction shown by the mentioned trough. The latter, anyway, could be easily interpreted in its central sections by a two-dimensional model structure: this approach will be the theme of another work focussed in this research sphere and concerned with a broader general picture.

Going back to the oval-like, sub-regional families of gravimetrical anomalies, it can be seen that their slopes are quite elevated; in addition to that, one could reasonably assume, at least at this stage of the interpretation procedure, that these three families do not interfere one each other.

A model approach, which seems both qualified to produce closed, elongated patterns of gravimetrical anomalies and simple enough to be easily managed ignoring cumbersome computational procedures, has been envisaged in the "thin dipping sheet" scheme, see e.g. Telford et al. 1976, pp. 66-68; this procedure appears to be useful for the present work and also interesting for future improvements, as it deals with various geometrical parameters affecting the thin dipping sheet: in other words, families of sheets might be adopted for more sophisticated interpretation works, preserving the same simple basic element. In particular, there the sheet dipping angles could be varied.

At this stage of the interpretation, the sheet is assumed to be vertical.

The theoretical relationship used to obtain the gravimetrical anomalies in milligals given by such an elementary structure is as follows ($\alpha = 90°$):

$$g = 4.07 \cdot 10^{-3} \sigma t \left[\frac{1}{2} \log \left\{ \frac{\{(h+l)^2 + (x^2 + Y^2)\}^{1/2} - Y}{\{(h+l)^2 + (x^2 + Y^2)\}^{1/2} + Y} \cdot \frac{(x^2 + h^2 + Y^2)^{1/2} + Y}{(x^2 + h^2 + Y^2)^{1/2} - Y} \right\} \right], \quad (1)$$

x being the abscissa, perpendicular to the sheet strike direction.

where the sheet symbols mean: σ, density (g/cm3); thickness; l, height; Y, semi-length; h, depth at its top (lengths are expressed in feet).

In Fig. 4, (a.) the model anomaly profiles are shown along the two selec-

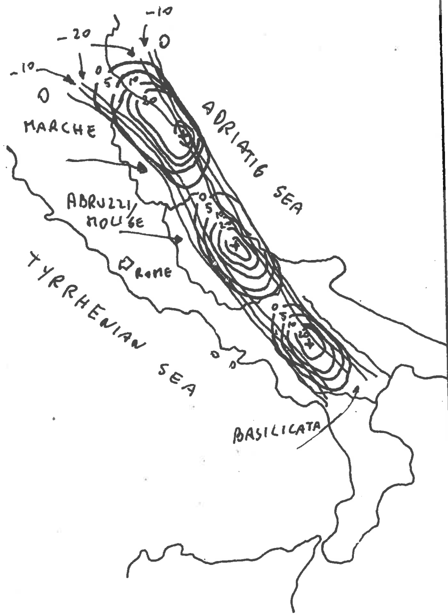


Fig. 3 - Regional and sub-regional gravimetrical fields, as obtained according to the procedure suggested by the text.
A synthesis of the geographical references is also shown.

Fig. 4, a)
Showing the sections of the two suggested thin dipping sheets, to interpret two families of the three ones, given by Fig. 3.
The sheets' data are as follow:

top depth:	10 kms,
bottom depth:	30 kms,
length:	80 kms,
thickness·density:	2kms·g/cm^3.

Both the sheets are supposed to be vertical.

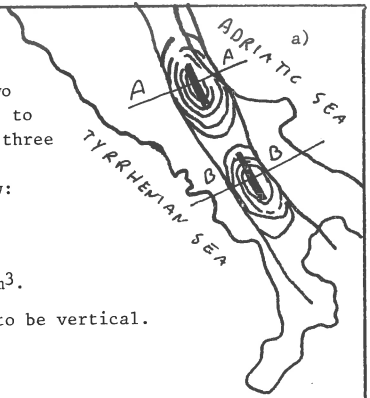
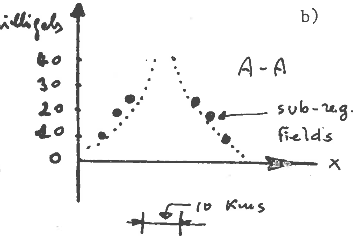
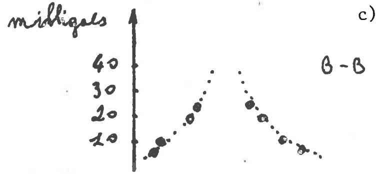


Fig. 4, b), c)

Two examples of the fits obtained by comparing selected thin dipping sheet theoretical responses (dotted lines) and intersections of sub-regional fields with opportune profiles, namely A-A, B-B, see a).





ted directions A-A, B-B, reproduced in the same Fig. 4,b,c; here the sections of the model structures, suggested for this first three-dimensional interpretation are located, together with the respective sub-regional anomalies of the considered gravimetrical fields for two situations, namely those ones related to Sulmona's and Potenza's deep structural highs. The geometrical parameters characterizing these structures are outlined in the same figure, (a).

A number of additional comments are considered useful in order to connect this interpretation trend with both the V-E/VS approach previously outlined as well as the mentioned seismological characteristic of this area, that is the "shallow seismicity" it shows.

As for a number of connections between the gravimetrical interpretation and the V-E/VS, one can remember that the suggested deep viscous model masses (supposedly squeezed by visco-elastic structures) could represent the model masses proposed by the gravimetrical interpretation: this squeezing effect has to be considered a local consequence caused by both the palaeogenic nucleous rotation and the African plate action, together with the reaction offered by the Eurasian plate, with reference to the Adriatic Sea areas.

Besides that, these (dense and viscous) model masses can be reasonably located in acceptable correspondence with at least two of the three deep structural highs, that is just where sub-regional gravimetrical effects, attributable to three-dimensional sources of anomaly, should be expected.

As for the northern deep structural high, related to Ancona, it can be seen that the patterns of this anomaly family are quite less regular than the ones previously dealt with: under this view point, a more detailed interpretation work should be needed in the future.

In addition to the foregoing, the inspection of the Pliocenic fault system - related to all of the three deep structural highs evidenced by the gravimetrical analysis - suggests the existence of deep stress conditions causing also these quite consistent surface symptoms. These surface evidences could be connected with drifts along S-W/N-E directions experienced by deep masses, forced to migrate according to respective, different residual velocities caused by large geo-structures acting within the frame of the broader geodynamic scheme previously mentioned.

As for the "shallow seismicity" problem, one can admit that the presence of actual, both ascending and drifting, deep masses like those ones pictured by the mentioned models, might very reasonably justify seismic stresses within upper, "less viscous" media. The latters should be schematically located "above" the viscous masses gravimetrically envisaged as thin sheets causing the oval anomaly families.

As a final consideration, one can verify that the two "belts" lying in between the three oval anomaly families are well known critical areas, as for concerns seismic events: drift velocity differences of the deep viscous masses could be reasonably responsible of these large-scale evidences.

CONCLUSIONS

This paper has shown that cross comparisons of evidences can be suggested to connect gravimetrical maps and seismic data with visco-elastic/viscous models (previously suggested), in the frame of an investigation devoted to study the shallow seismicity causes along the Eastern side of Italian peninsula.

The proposed trend - which includes a number of methodologies expressly elaborated for - appears able to utilize groups of geo-data on the basis of an approach supported by quantitative interpretations of sub-regional, gravimetrical anomalies.

The obtained results have to be considered of noticeable importance in planning proper locations of further geophysical surveys, like e.g. groups of magnetotelluric soundings.

ABSTRACT

Italian peninsula Eastern side is apparently interested by a number of characteristic evidences, which involve seismic activity, topography, both regional and sub-regional gravimetrical aspects, Moho's isobates, scattered Pliocenic tectonics as well as Upper Miocene sedimentation. A very schematic assembling of elementary visco-elastic and viscous structural elements had been suggested to represent a number of geodynamical features of the studied areas. The gravimetrical model deep structures of the proposed interpretation seem able to account for a first synthetical, also seismotectonical picture of the above mentioned evidences, with reference to a 10 Myrs time interval. Additional possible border conditions and/or constraints are envisaged to improve the reliability of this interdisciplinary interpretation approach.

ACKNOWLEDGMENTS

This work has been carried out in the frame of the studies sponsored by the Ministero della Pubblica Istruzione, Roma, and NATO Research Grant R.G. 119.81. Connections with investigations sponsored by C.N.R. (Progetto Geodinamica and Progetto Energetica) should be emphasized.

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LUMINOUS PHENOMENA AND OTHER PARTICULAR EVENTS BEFORE, DURING AND AFTER EARTHQUAKES IN THE CARPATHIAN BASIN

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The Carpathian Region can be defined as a geographical complex, consisting of two main tectonic units. The first unit is the Carpathian Basin which is bordered from the northwest, north, northeast, east and southeast by the Carpathian Mountain System. This system represents the second unit. Seismologically two areas can definitely be distinguished. The first is the Vrancea Area at the southeastern corner of the Carpathian Mountain System. This region is characterized by intermediate shocks with a focal depth ranging from 70 to 200 kilometres. The second area is represented by the rest of the Carpathian Region, having shallow shocks exclusively with a focal depth usually much smaller than 70 kilometres.

In the course of the investigation I considered all the historically known earthquakes that took place in the Carpathian Region during the last 1500 years, provided that the epicentral intensity reached 6 degrees on the Mercalli scale which has altogether 12 degrees. Using Kárnik's equation, $M = 0{,}53\ I_o + 0{,}96$, which is valid for the Carpathian Region, I found that $I_o = 6$ degrees corresponds to $M = 4{,}1$ approximately, where M is the Richter magnitude and I_o the epicentral intensity. That is all shocks were taken into account for which the Richter magnitude reached 4,1. I used all the available earthquake catalogues, and more than 24 years ago I had the lucky opportunity to study the archive of the formerly existed Hungarian Seismological Institute where hundreds of unpublished, original, handwritten reports on shocks of last centuries, or exact copies of them, were collected. The estimation of the epicentral intensities was made on the basis of the existing catalogues as well as by using this invaluable archive-material.

During the last 1500 years altogether 332 shocks reached at least M = 4,1. On the basis of these data a map of the areal distribution of the total seismic energy has been constructed in which isoenergetical lines connect those points of the surface over which the summarized seismic energy-release was the same. The greatest maximum is to be found, naturally, in the Vrancea Area. This map, as well as the graph of the strain-rebound characteristics, and other drawings, that were shown during my lecture, will be treated in detail elsewhere. Here I wish to concentrate myself only for the brief discussion of earthquake light phenomena /EQL/ and to some other unusual events that were associated with them.

/a/ General remarks. According to my maps, showing the geographical distribution of EQL in the Carpathian Basin and outside it, in Romania, almost all the events occurred in hilly and/or mountainous areas. Only three cases are known when this phenomenon occurred in plain-regions. The town of Komárom in Hungary, which suffered rather strong shocks in the last centuries, including a quake with M = 6,3 and another one with M = 6,0, belongs to this latter category, but it lies just near the great, seismoactive fault-line, represented by the valley of river Danube.

The Vrancea-events demonstrate that EQL can occur in the case of intermediate shocks, too, and not only when shallow earthquakes are in progress.

In some occasions, particularly at Komárom in 1763, the lights were associated with gas eruptions and/or strange - often sulfurous - odor. The association of EQL with gas outbursts is in accord with modern theories of the luminous phenomena accompanying earthquakes. Gold and Soter /1980/ have pointed out the possibility of effective burning of gases, as a possible source of EQL. Noszticzius /1979/ has suggested cold glittering due to chemical luminescence as a result of reactions between certain gases of the air and unknown gases from the soil. Hédervári /1981/ has emphasized the analogy between EQL and the lunar transient phenomena which are attributable to gas eruptions from the Moon's interior, helped by tidal displacements of certain parts of the lunar crust, outlined by fractures, -- and associated with moonquakes, as it was demonstrated by Middlehurst and Moore /1967/. Hédervári also stressed the importance of /regional/ crustal deformations prior to impending shocks as a phenomenon which creates ruptures in the soil, permitting thus the outburst of the gases from the depth to the surface or the air. In this case the occurrence of the lights may be the function of the magnitude of the shocks in question, because a larger crustal deformation can lead to the occurrence of a stronger shock, having large energy-release, and the larger the energy-release, the larger is the extent of the area over which EQL can be observed.

In this context it should be mentioned that all the EQL that were seen in the Carpathian Region during the last 1500 years were associated with rather strong shocks of a Richter magnitude of at least 4,7 or over it. Weaker earthquakes were never accompanied by EQL. And: the greatest shock during the last one and a half millenia was the earthquake at and around Bucharest in 1940, having a Richter magnitude of 7,3. This shock /that originated in the Vrancea Area/ was accompanied by many hundreds of lights over a great area, measuring about 450 x 500 kilometres /Demetrescu and Petrescu, 1941/. And, as a further proof for the correlation between the extent of the EQL-area and the greatness of the associated earthquake, the 1933 Sanriku shock and tsunami can be mentioned, when the shock reached M = 8,9 /Richter, 1958/ and EQL were seen along an arc from Hokkaido as far as Tokyo, over a distance of some 1000 kilometres /Musya, 1934/.

/b/ Case histories from the Carpathian Region. In the followings some examples will be summarized briefly on the basis of a few authentic sources /Réthly, 1952, Demetrescu and Petrescu, 1941, Xántus, 1977, personal communication/.

/1/ 1607 November 27, Nagybiccse. E: 18° 33' E, 49° 13' N, M = 4,7. At about 7h on the evening an aurora /?/ was seen on the sky, and simultaneously with an earthquake and a loud noise, "a fire" dropped down. Aurora /polar light/ is not probable; such an event is not mentioned in the aurora-catalogue of Berkes /1943/. A possible explanation may be, naturally, a meteor-fall, but its simultaneity with the shock is very much unlikely. Another possibility is an earthquake light of the fireball type.

/2/ 1615 January 5, Érsekujvár. E: 18° 10' E, 47° 59' N, M = 4,7. Within the aurora /?/ the sky "splitted" and "fire dropped" down from the heaven in the moment of a shock, accompanied by rumble. The phenomena were observed in the neighbouring villages as well; some people mentioned a strange rainbow, others spoke about a meteor. Similarly to case /1/: aurora is not likely; it was not mentioned by Berkes /1943/. Earthquake like appears to be the possible explanation.

/3/ 1724 January 29, Késmárk. E: 20° 26' E, 49° 08' N, M = 4,7. Two shocks at 20h 45m and 23h 15m, respectively. On the western sky a fire-like light has been seen.

/4/ 1763 June 28, Komárom. E: 18° 05' E, 47° 48' N, M = 6,3. This earthquake was perhaps the strongest one in the last 1500 years in Hungary. It was strongly felt in an area of 87 000 km^2 within the country. Ruptures in the soil originated on thousands and thousands of places. From almost all of them water and quicksand were emitted in the company of flames and stinking smoke. In the town numerous wells lost their water and black sand was seen instead of it, but in other wells the level of the water began to rose very fastly and reached the edge of the well. In some of the ruptures, - from which often hot or boiling-like water rushed up at first - the water dried up soon. The river Danube began to rise as it would have wanted to swallow the town. The waves were "tower-high" ones and the water appeared to be steaming as it would have been in a boiling stage. It had a sulfurous smell. The majority of the ruptures came into existence near the river-bank and from some of them flames emerged alternately with sand and smoke. In the castle /fortress/ a yellow flame erupted having a thickness of a human arm and it had a sulfurous odour. After the disappearance of this flame turbid water and again sulfurous sand appeared in great quantity. The moat around the fortress was filled with sand, sulfur and water, up to four feet in height. The Fertő Lake, at a distance of 100 kilometres west of Komárom began to be restless /seiche?/ and foamed intensively. In some places in and near Komárom the waters that were erupted from the ruptures became salty. Flames were seen over river Danube, and these flames were "so big as a barrel". Many horned cattles were perished by the stining vapour that came from the earth. In Esztergom, a town east of Komárom in a distance of some 50 kilometres, "fire came down from the heaven". It was similar to a rain of fire. The shock at Komárom was also accompanied by lights. In some places mud was erupted from the soil and sparks were seen here. At the bank of another, but smaller river, Vág, the colour of the flames, rushed up from the ruptures, was red, and the water, that came after, was again sulfurous in character. In the inundation area of river Danube, small cones of mud came into being. At some places the waters, that were issued from the soil, were distinctly black in colour. The water of the river Vág appeared to be in a boiling state, similarly to the case of Danube. The sand, erupted from the ruptures, was black in many places, but lost its sulfurous odour within some days. Seeing from the ships on the Danube, the town of Komárom appeared to be covered by black clouds.

/5/ 1799 April 6, Homonna. E: 21° 50' E, 48° 56' N, M = 4,7. Moving fire /or light/ was seen above the fields.

/6/ 1783 April 22, Komárom. E: 18° 05' E, 47° 48' N, M = 6,0. This was the second, very large shock at this place. New ruptures originated from which sand and water was emitted. Sulfurous smell was often felt. At the end of June and in the first half of July the image of the Sun and Moon was like the blood in colour. According to old descriptions this strange phenomenon was caused by "dense vapours" and many people claimed that the vapours were issued from the soil as a consequence of the quake at Komárom. In reality, however, this phenomenon had nothing to do with the shock. It was the result of the great volcanic eruption-cycle in and around Iceland.

In 1783 and 1784 not less than eight volcanic centers have been in an active stage there. The most powerful eruption was that of Laki, a fissure with a length of some 25 kilometres /Berninghausen, 1964/. Meteorologically it was a very remarkable event that polluted the air over central and northern Europe, as well as Minor Asia for many months.

There were, however, true EQL at Komárom; "glowing meteors" were often observed over the epicentral area. These might have been fireball-type earthquake lights.

/7/ 1806 September 22, Komárom. E: 18° 05' E, 47° 48' N, M = 5,2. A short time before the occurrence of the shock lightnings were seen two times. Note that these phenomena were observed not in Komárom, that is in the epicentral area, but in Pest /the eastern part of the capital of Hungary/. The sky was clear, full with stars, therefore the flashes are not attributable to storms. In the theatre there was a great panic because somebody began to cry: "The theatre is in fire!" But in fact no conflagration occurred. The distance between Pest and Komárom is some 80 kilometres.

/8/ 1809 November 17, Eperjes. E: 21° 15' E, 49° 00' N, M = 4,9. The shock was accompanied by "belching of fire". The air appeared to be full with fires during the earthquake as a whole.

/8/ 1829 July 1, 2, 4, 7, 27, and August 30, Piskolt and its environs /Érmellék district/. E: 22° 17' E, 47° 34' N, M = 5,5. From the town of Debrecen at 20h 28m on July 1 reddish clouds were seen near the horizont and a light-phenomenon, too, which lasted only to two seconds, having a glittering character. At this time or a very little later three earthshocks were felt, accompanied by subterrain murmur.

/9/ 1838 January 23, Transylvania, Torda. E: 23° 47' E, 46° 34' N, M = 5,5. At Brassó / = Braşov / strong noise was heard and "thick vapour" was seen in the air. At Felső-Detrehem an "electric phenomenon" was also seen prior to the shock, but its true nature is not clear enough from the original report which was written on an archaic Hungarian language. In the night fires were seen here and there in the town of Temesvár / = Timisoara /. These fires occurred prior to the shock.

/10/ 1851 July 1 and 2, Komárom. E: 18° 05' E, 47° 48' N, M = 5,2. Lights were seen in the air, immediately after the shock.

/11/ 1852 November 15, Sasvár. E: 17° 09' E, 48° 38' N, M = 4,7. At the moment of the first shock strong lightning was observed.

/12/ 1869 May 29, Besztercebánya. E: 19° 09' E, 48° 44' N, M = 4,1. Fires were seen during this quake that had a relatively small magnitude. These phenomena, however, by all likelihood were not true EQL but northern polar light. This was the impression of the observers, and this is proved by the catalogue of Berkes /1943/, according to which aurora were really seen at first on May 13 and secondly on May 29, although the solar activity at this time was relatively mild.

/13/ 1880 October 3, Central Transylvania. E: 23° 45' E, 46° 22' N, M = 5,7. On one place a peculiar light-phenomena was seen; details are lacking.

/14/ 1940 November 10, Vrancea Area. E: 26° 42' E, 45° 48' N, M = 7,3, h = 133 km. As already mentioned, over an area of 450 x 500 kilometres many, different lights were observed /Demetrescu and Petrescu, 1941/, including the following events: total or partial illumination of the sky or the air /number of observation: 52/; lights similar to lightning /51/; sparks /8/; streaks, rays, luminous arcs /34/; balls, brilliant spots, often together with sparks /18/; flames, tongues of fires, flares /31/, etc.- In some cases the lights were moving from the soil upward, in other cases they moved in the opposite directiom. The colours were red, yellow, green, bluish-white and violet, respectively. There were lights that moved in the rythm of the tremors. At a certain place the flame "reached the clouds" and illuminated the nearby mountain. Particularly interesting is that in some cases "lightnings" and lights, having the form of a plate, were seen in motion within rooms. The majority of the events occurred simultaneously with the shock; a few prior to, some other after the shock.

It is very remarkable that in the direction of the occurence of the lights no correlation was found with the direction of the epicenter.

/15/ 1977 March 4, Vrancea Area. E: 26° 48' E, 45° 48' N, M = 7,2, h = 95 km. From Brassó, red streaks and draperies were seen for 20 minutes on the western horizont /opposite to the direction of the epicenter!/. Many people attributed these lights to a conflagration, beyond the horizont. From Ploesti the lights were so strong as the daylight. After 10 or 15 minutes, a gigantic sparklike or lightninglike flashing was seen that illuminated the half of the sky. It is noteworthy that this latter phenomenon occurred after the shock, which is a rather unusual event /Xántus, 1977, personal communication/.

/c/ The EQL-project. As earthquake lights can be regarded as important precursory events of impending earthquakes, although, as mentioned, in some occasion they were seen during and/or after the shocks, too, the collection and publication of observed materials of EQL, in a systematic form, and within the frame of the Subcommission on Earthquake Prediction Research is recommended. This suggestion of the lecturer has been discussed at the Leeds-meeting and was approved. Accordingly the

Project on Collection and Evaluation of Data on Earthquake Light Phenomena

has been initiated. The organization of the EQL-project is now under progress. Those persons and institutions who are interested about it and would be a participant in the cooperative work, are kindly requested to establish a direct contact with the Georgiana Observatory, H. 1023 Budapest, II. Árpád fejedelem útja 40---41, Hungary.

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