BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD

BMR RECORD 1982/42

REPORT ON AN OVERSEAS VISIT TO
THE UNITED STATES AND BRAZIL,
1 - 18 SEPTEMBER, 1982.

by

B.J. DRUMMOND

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SUMMARY

This record describes a visit to the United States and Brazil in September, 1982. The principal purpose of the visit was to attend the International Symposium on Archaean and Early Proterozoic Geologic Evolution and Metallogenesis (acronym ISAP), and the business meetings of several working groups of the Inter-Union Commission of the Lithosphere which co-sponsored the symposium. En-route to the symposium, I visited several earth science institutions in the western United States.

The main reasons for the visits to the US institutions were three-fold. Firstly, I wanted to study the state of the art in seismic refraction equipment, field procedures and interpretation techniques in the United States. I found their equipment very similar in concept to ours, their field procedures slightly different because they are more likely to have laterally varying structures, and their interpretation techniques more sophisticated because of the need to account for lateral structures.

Secondly, I was interested in the methods of linear inversion of seismic data, to give models with extremal bounds, that are being developed at several of the institutions. I found that the techniques might be useful for interpreting good quality data, but the extremal bounds placed on the models are often so generous that their usefullness is suspect.

Thirdly, I wanted to gauge the feelings about the various computer systems that can be set up to process seismic reflection data. No single computer seems to be favoured, and the aspects that we should consider in any computer system are (i) flexibility of operating system software, and (ii) the ability of the system to expand to cope with the very large data sets likely when 1024-channel full-bit systems are operational.

Papers on numerous topics and of variable quality were presented at the ISAP. A most significant aspect of the conference was the number of papers which presented models of Archaean crustal evolution in which the crust grew by lateral accretion. However, no consensus was reached about a single, likely, although simplistic, model. Most of the papers were geological; very few presented geophysical results, and almost no attempt was made at a multidisciplinary approach in any of the studies.

Working Groups 3 (Proterozoic Lithosphere Evolution) and 4 (the Archaean Lithosphere) of the ICL held their first business meetings at the ISAP. The next business meeting of both groups will be held in China in September, 1983, where the groups will co-sponsor a symposium on tectonic boundaries in the Precambrian. The 1984 business meeting will be at the IGC in Moscow.

Very little business was conducted at the meetings, because both groups are still trying to ascertain what work is underway and planned in each country. The proposed Australian programme based on lithospheric transects has been taken as an example for other countries to follow.

1. INTRODUCTION

In September, 1982, I attended the International Symposium on Archaean and early Proterozoic Geologic Evolution and Metallogenesis (acronym ISAP), held in Salvador, Bahia State, Brazil. En route to the ISAP, I visited four earth science institutions in California. While at the ISAP, I attended workshop meetings of Working Groups 3 (the Proterozoic Lithosphere) and 4 (the Archaean) of the International Lithosphere Project. The detailed itinerary is given in Appendix 1.

The purpose of this report is to summarise the results of these meetings and visits and to combine into one document all of the information which I, and other officers of BMR may find useful if future visits to these centres should eventuate.

The report is in four parts. The first part deals with the visits to the earth science institutions in the US, and is in the form of notes about the work of individuals I talked to, and were made at the times of the visits. They are listed in the order of the visits. The second part of the report deals with the ISAP. The style of the symposium is described, and summaries of some of the papers are given. The third part of the report report deals with the meetings of the Working Groups of the International Commission on the Lithosphere. The minutes of the meetings are given in Appendices. Finally, the fourth part of the report summarises the problems which I tried to address during my visit, and the advice and possible solutions I was able to find overseas.

2. VISITS TO GEOSCIENTIFIC INSTITUTIONS IN THE UNITED STATES.

The reasons for visiting these institutions were:

(i) To study the state of the art in seismic refraction recording techniques and survey design in the United States,

(ii) To study methods of linear inversion of seismic refraction data,

(iii) Wherever possible during the limited time available, to talk about the types of computer systems being used for seismic data processing, especially reflection processing, and to try to find out why some computer systems are preferred over others, and

(iv) To answer queries raised by other geophysicists in BMR about the use of the HYPOELLIPSE earthquake location program, and the stacking

of marine seismic reflection data across canyons and trenches.

OFFICE OF EARTHQUAKE STUDIES,
UNITED STATES GEOLOGICAL SURVEY,
MENLO PARK.

I had written to Jim Dieterich, Director of Earthquake Studies, setting out the reasons for my visit. They were to talk to Jack Healy and Walter Mooney about their explosion refraction seismic studies and to John Lahr about about the computer program HYPOELLIPSE.

WALTER MOONEY

I spent most of the day with Walter Mooney, who is now in charge of the refraction studies group, looking at his instruments and refraction data.

INSTRUMENTS:

The basic design concept of their remote recording field seismographs was conceived by Jack Healy for his work in Saudi Arabia, and the detailed design and construction of the instruments, and of the playback system, were done by contractors. Originally, 150 recorders were planned but only 100 were built, because of the fear that too many instruments would cause logistic problems in the field. This is contrary to our notion that the more recorders available, the lower the field costs and the easier the logistics.

The USGS has set up five trucks (vans), each with 20 instruments. The trucks have racks along each side to house the instruments for transport. When the trucks are parked and the instruments not in use, the instruments are plugged into the mains power to keep the internal batteries charged. Five technical officers, usually, but not always, university graduates with degrees in geology or geophysics, each look after a truck and its instruments and attend to all digitising when required.

The instruments are completely self contained. The seismometers (Mark Products 2Hz) are clamped into the base of the transit case for transport. Next to the clamped seismometers are the plugs for cable input and output and the battery charger input. A bottom lid clamps over the seismometer and plugs to protect them during transport. The top lid can be unclamped to reveal the three seismic amplifiers (for three gain levels,

each independently set, or switched out to allow just the seismometer output to be fed directly to the tape deck for recording close to blasts), radio for WWV and clock. The three seismic channels are multiplexed onto one frequency modulated recorder channel.

The tape deck is a six-channel cassette recorder, bought commercially. Four channels are used at present; they record the seismic signals, the clock, radio and speed compensation signal. The two remaining channels are not used at present, but may be used in the future for horizontal seismometers. Ordinary audio cassettes are used.

The recorders can be switched on by the clock for up to ten periods a day, each period lasting up to thirty minutes. Switch-on is actually just before the programmed time, and in this time the recorders automatically calibrate themselves.

PLAYBACK SYSTEM:

Tapes are played back at the recording speed. USGS use an electronic time decoder similar to ours, a two-channel chart recorder to monitor the seismic channels to allow them to choose which gain level to digitise, an analog-to-digital converter, a Tectronix video terminal, and a plotter, all run by a microcomputer. Data are stored on floppy discs at 5 m.sec sample interval. There is talk of halving this. They generally sample 30 - 40 s. The playing back of tapes is fully automatic. The operator mounts a tape, the decoder reads the time code, which also has a coded signal that identifies the recorder, the computer works out the nearest shot (in time) and when to start digitising, and then automatically starts digitising. The data can be plotted as record sections, using the data base for information about epicentral distance, etc., or transferred to a larger computer. There they are stored on a demountable disc pack for transfer to digital magnetic tape or any other computer. The playback system fits into two boxes each about two-thirds of a metre cubed and is taken into the field to produce record sections.

USGS (Office of Earthquake Studies) have four computers (VAX 11/780 and PDP 11's) of various sizes and configurations for data processing and general computing.

ENERGY SOURCES:

USGS use blasts in holes drilled by contractors. They use up to one tonne of explosives in any blast, with all of the explosive in one hole, which they dry tamp.

SOFTWARE:

All of the software for the digital processing of the seismic data, including the programs which set up the data bases and control the digitising, was written by contractors employed specifically for this purpose. USGS seems to have no qualms about letting contracts for such things.

DATA:

I looked at a lot of Walter Mooney's data, and discussed with him the optimum station spacing in seismic refraction studies of the Earth's crust. They usually work on a 1 - 2 km spacing, but with the ability to produce record sections in the field they can close up the spacing if warranted by the field results. The rule of thumb is that spacing should be less than one wavelength of the seismic energy. In our exercises in outback Australia, where logistic pressures often dictate how much time we can spend in the field, this is not possible, and in areas of relative lateral homogeneity may not matter. However, in California the USGS find that the lateral structures are very severe, and that a very small station spacing is necessary. We should keep this in mind when undertaking ACORP projects which are designed specifically to look at areas where lateral velocity changes occur (eg. central Australia).

INTERPRETATION:

Several of their geophysicists use and interpret the data, and their technical staff are also encouraged to try interpreting data. They have the usual sorts of programs to display their data, eg. production of survey maps, record sections, etc., as well as ray tracing programs and most of the popular synthetic seismogram programs. However, their most useful program is the McMechan & Mooney (1980) version of Cerveny's synthetics program which copes with models with lateral structure and both lateral and vertical velocity variations within the layers. We have the program and are trying to implement it on our Hewlett Packard 1000 series computer. I talked to Walter about the problems of segmenting and overlaying the program, and whether any significant loss of precision would occur on a 16-bit computer. He thought that we should have few problems.

FUNDING:

Funds for the program of refraction seismology come from a variety of sources. The survey provides the bare bones budgeting; the rest comes from contracts that they take on, eg. site surveys for nuclear power stations, geothermal energy, and the Survey gets the added spin off of data on which they can do research into crustal structure and the evolution of the western United States.

JOHN LAHR

John provided me with a magnetic tape with the source code of his latest version of HYPOELLIPSE, as well as new and up-to-date user instructions. The observatories group at BMR have been using this program to locate earthquakes in the Australian region, but were having troubles when they tried to locate more than one earthquake in any computer run. John went through the flow chart of the program with me, and looked at some test data I had taken with me. The problems were arising because of an ambiguity in the user instructions, and hopefully the notes I made will clear up the problems.

DEPARTMENT OF GEOPHYSICS,
SCHOOL OF APPLIED SCIENCE,
STANFORD UNIVERSITY.

JON CLAERBOUT

I met first with Jon Claerbout who showed me his computer system. He has a VAX 11/780 computer with a Floating Point Systems array processor and 1420 Mbyte of disc. He and his students develop the theory and software for seismic reflection processing and therefore attract large amounts of money from exploration companies. The computer system was bought with money from an annual gratuity from 30 companies.

To facilitate their software development, they have developed very sophisticated visual display software, much of it written by Rick Ottolini, who demonstrated some of it for me. They store a full data set in the core of the computer, and then massage it in several ways. The data sets demonstrated to me were:

(i) A marine reflection profile,

(ii) The GSI Gulf of Thailand 3D reflection data,

(iii) A geometric design of three linked cubes which rotate about an axis and are cut by several rods which cross the model from right to left and left to right, and

(iv) Teaching exercises in which waves are generated synthetically at a number of points in space and time, reflected and refracted at points and surfaces, and then removed to teach migration.

Describing them in order:

(i) The data from a MARINE REFLECTION PROFILE are stored in the computer as a three-dimensional array, the three dimensions being shot-point number, two-way travel-time and distance along the streamer cable. The data are moved off disc into the computer core in frames, each frame consisting of the total record section of data from one shot-point, and the various frames representing all of the shot-points (see Figure 1a).

As the frames are moved into the core, they are displayed on a TV screen. Thus, they are displayed in a time sequence as if the ship were moving along. However, as the ship position is fixed on the screen, the reflection points move across the screen in time as frame after frame is put on the screen. Thus, a movie of data flashes on the screen

Once the data are in the computer, they can be sliced along the shot-point number (Fig. 1b), time (Fig. 1c) or geophone (Fig. 1d) directions, and displayed on the video screen. Sequential slices along any axis can be displayed one after another to produce movies. Thus the direct, reflected and refracted phases can be seen interacting in time and space. Specific portions of the movies can be frozen on the screen and plotted on a dot matrix printer (Figures 1b, 1c & 1d). The movies are an excellent teaching aid, and are used in undergradu.te courses. By using the interplay of colours and grey scales on the video screen, phases can be accentuated or muted to study phase amplitudes.

(ii) THE GSI GULF OF THAILAND 3D DATA SET.

These data can be stored in the computer as a 3D data set, and then displayed on the screen, either as single slices along any of the dimensions, or as movies. The Stanford Group think that this allows easier interpretation of the data.

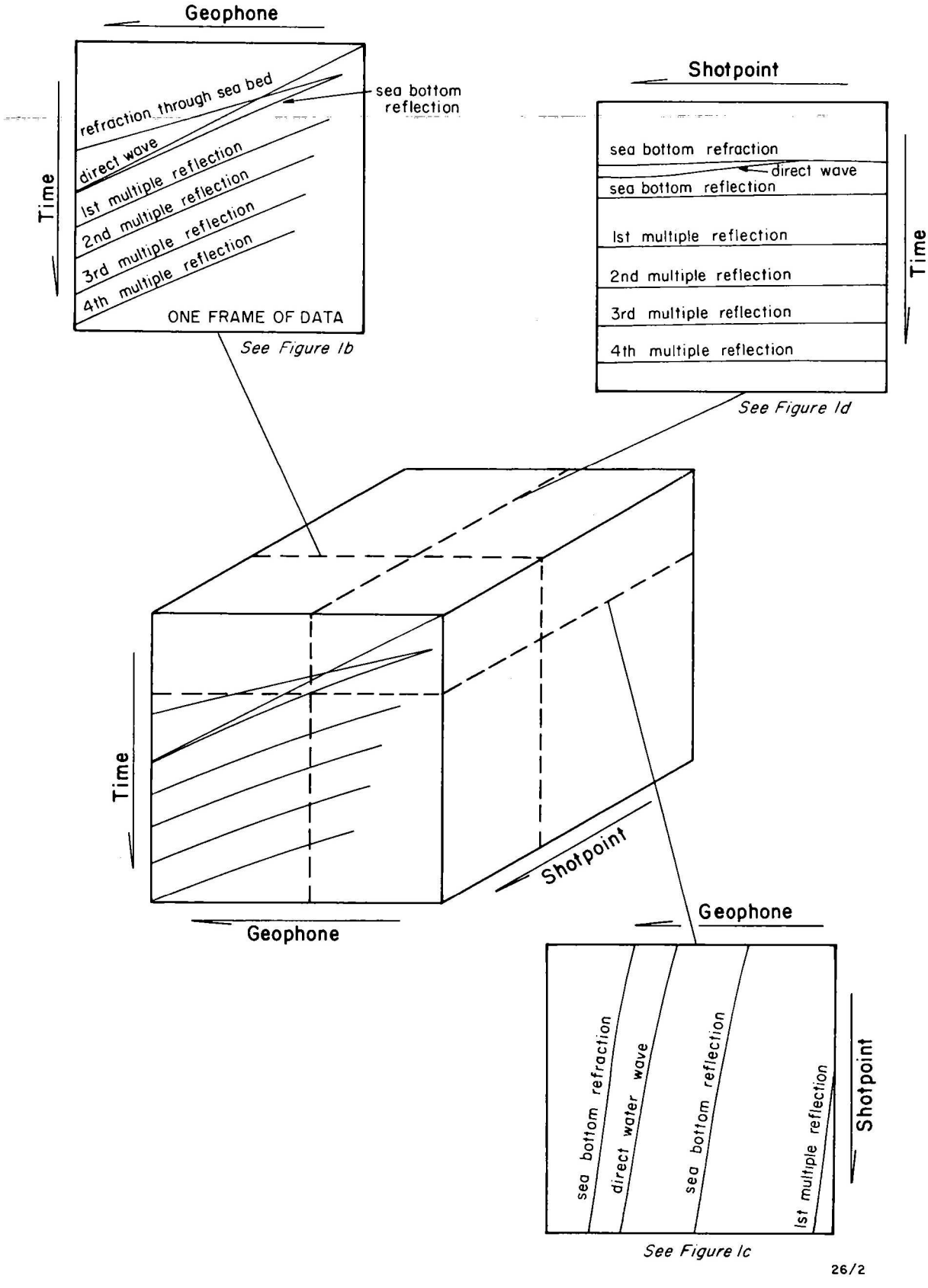
Geophone
Time
refraction through sea bed
direct wave
1st multiple reflection
2nd multiple reflection
3rd multiple reflection
4th multiple reflection
sea bottom reflection
ONE FRAME OF DATA
See Figure 1b
Shotpoint
sea bottom refraction
direct wave
sea bottom reflection
1st multiple reflection
2nd multiple reflection
3rd multiple reflection
4th multiple reflection
Time
See Figure 1d
Time
Shotpoint
Geophone
Geophone
sea bottom refraction
direct water wave
sea bottom reflection
1st multiple reflection
Shotpoint
See Figure 1c
26/2

Figure 1A.

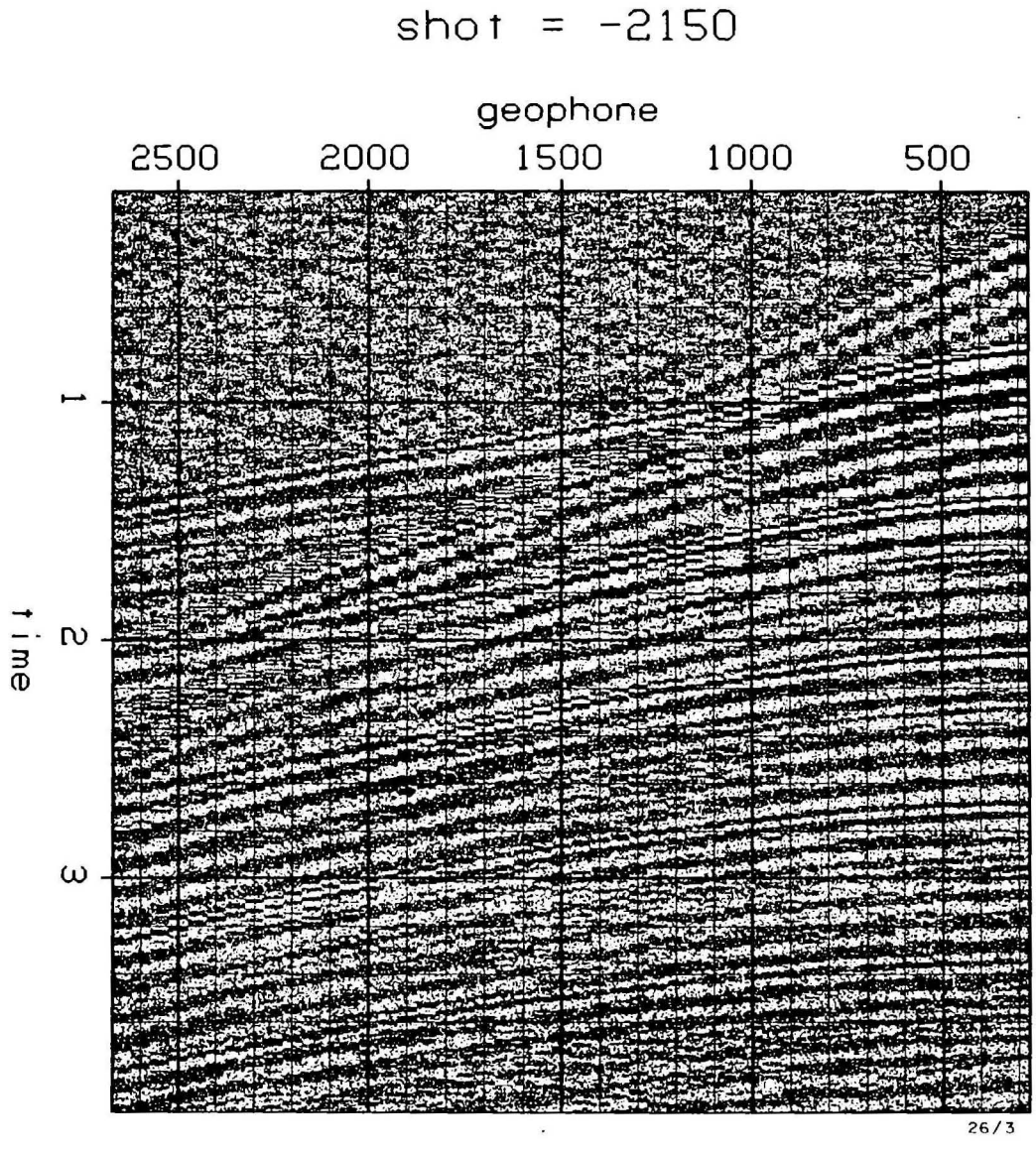

Figure 1B.

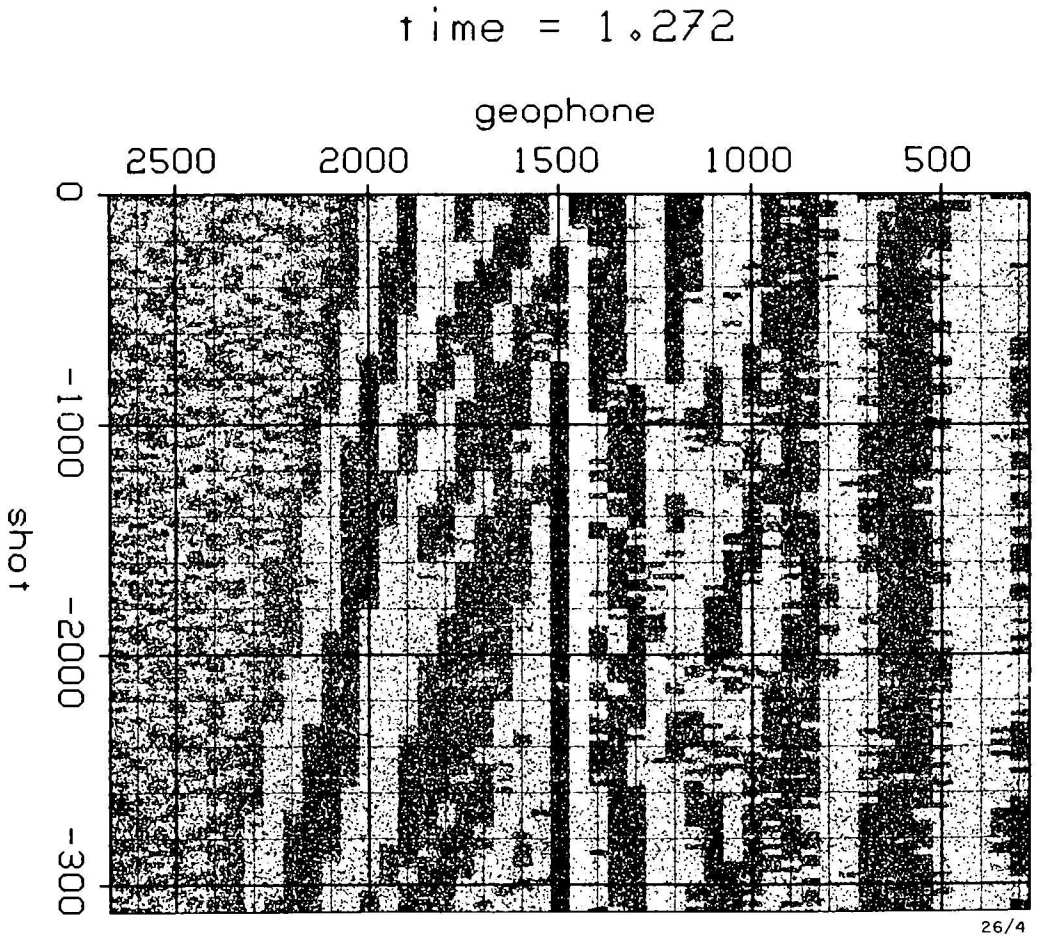
time = 1.272
geophone
2500
2000
1500
1000
500
shot
0
-1000
-2000
-300
26/4

Figure 1C.

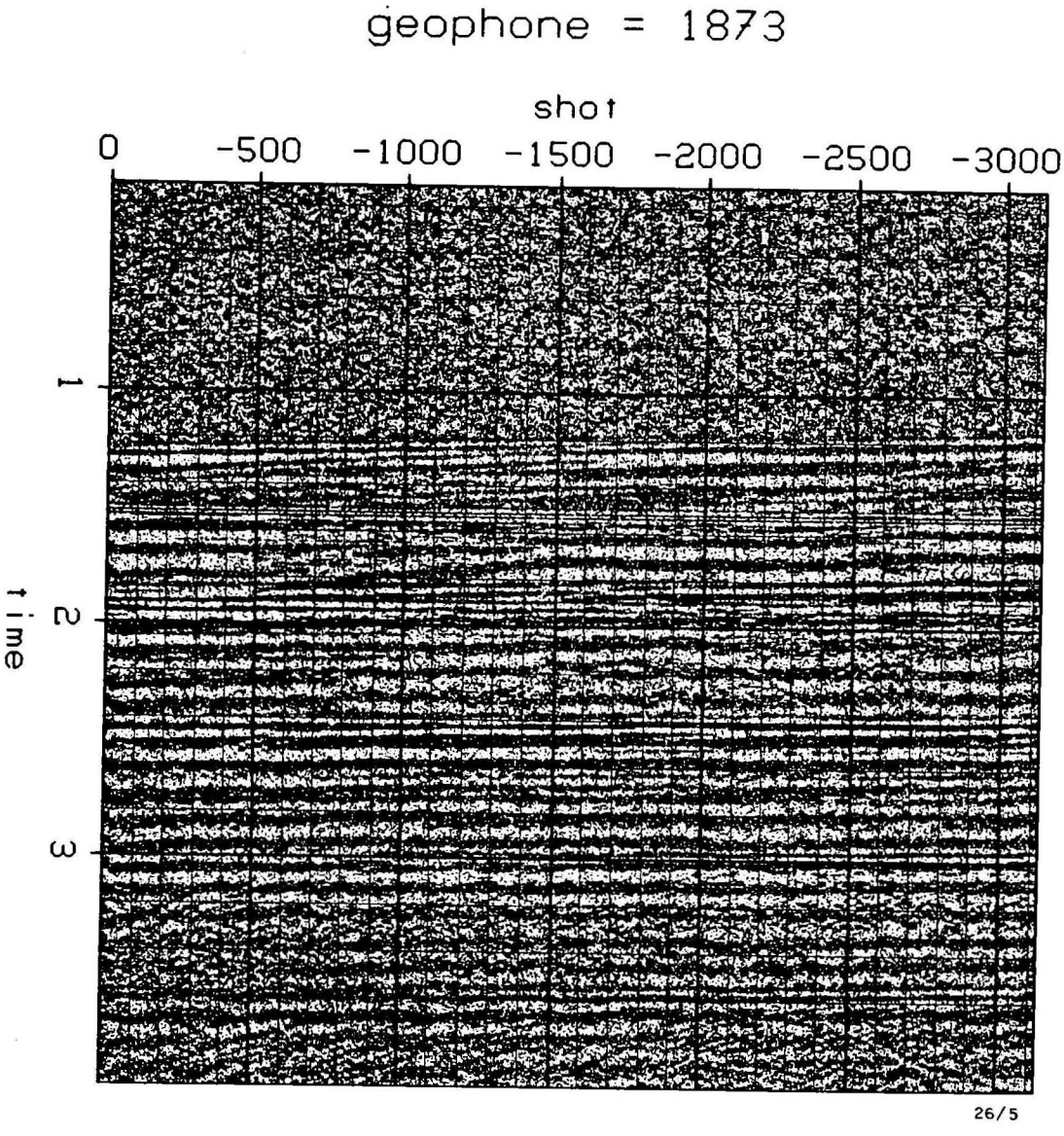
geophone = 1873
shot
0
-500
-1000
-1500
-2000
-2500
-3000
time
1
2
3
26/5

Figure 1D.

(iii) GEOMETRIC DESIGNS.

With the advent of three-dimensional data sets, especially when single profiles are stored as three-dimensional data sets, the need has arisen for interpreters to think in the dimension of time, ie. to interpret data plotted in the dimensions of shotpoint number and distance, or shotpoint number and two-way travel time, where shotpoint number represents the added dimension of time. The Stanford group have therefore developed some data sets which show geometric designs which move in time. Interpreters can play with these designs and slice the data sets in time to familiarise themselves with workng in the extra dimension.

(iv) TEACHING EXERCISES.

Waves generated synthetically for models with simple geometric shapes of known acoustic impedances are used to teach students how waves propagate through the earth - they can watch movies of the waves on the screen. These models can also be used to teach the fundamentals of migration.

GEORGE THOMPSON

George Thompson is Professor of Geophysics, and his main interest is in applied geophysics, especially the application of COCORP data to structural problems. HELOISE LYNN, one of George's students, recently finished her PhD. on the migration of seismic reflection data. She worked on several projects, including the Wind River Thrust data. With considerable effort, she managed to migrate the data sufficiently to show that the Wind River Thrust is a listric thrust, extending to the base of the crust. The overthrust portion is now mostly eroded. Thus, there is considerable vertical movement at the surface, but movement at depth is mostly horizontal, and there is no present-day thickening of the crust. The thrust also has subsidiary listric faults (thrusts also?) on the hanging wall side. His group has also migrated the Rio Grande Rift data to show that most of the near-surface faults are listric faults. This was previously unknown because most of the earlier work on these data looked at structures deeper in the crust, and the shallower data were ignored.

Heloise Lynn also worked with George Thompson on the nature of granite

batholiths, which they decided on the basis of COCORP data were flat-lying, and on the nature of the lower crust based on the character of seismic reflections. They concluded that the strong, laterally discontinuous reflections from the lower crust must be caused by the constructive interference caused by thin layers (60 m thick, approximately) of alternating high and low velocities. George was looking at lower crustal kimberlite nodules from the Colorado Plateau to try to get a feel for the rock types likely in the lower crust, and was very interested in the work of Ferguson & others (1979) on the nature of the lower crust in southeast Australia.

Another of George's students is looking at the types of rocks that could cause the strong reflections observed along thrust zones such as the Wind River Thrust. He has made velocity measurements in mylonites collected from thrust zones and has concluded that anisotropy in the mylonites due to the alignment of phyllosilicates is unlikely to be the cause of the reflectance (Jones & Nur, 1982). Constructive interference caused by laminae of rocks with differing degrees of mylonisation is more likely to be the cause of the reflectance.

George is at present pondering the tectonics of the Basin and Range Province in the western United States. There, the crust appears to be thinning owing to a series of listric normal faults. However, the surface, rather than subsiding, as would be expected from isostatic compensation of a thinning lithosphere, is actually uplifting. Seismic velocities in the upper mantle are anomalously low, so it appears that low density rocks are being emplaced into the upper mantle during crustal thinning, and account for the surface uplift.

SCRIPPS INSTITUTION OF OCEANOGRAPHY,
GEOLOGICAL RESEARCH DIVISION.

JOHN ORCUTT

I wanted to see John Orcutt because he has been working on the linear inversion of seismic refraction data. He has many papers published on the Tau-P method, eg. Orcutt & others (1980), and is starting to consider a least-squares method of inverting data using the amplitudes of the data as well as their travel times. For the method to work, the recorded data must be very good. A model is calculated by the Tau-P method, and its synthetic seismograms calculated by the WKBJ method. The synthetics are compared

trace by trace with the recorded data, and the model iterated to reduce the RMS residual between the amplitudes of the recorded and synthetic data. He started this work about two years ago but has not written it up yet.

I spent several hours with one of his students, KEVIN MACKENZIE, who showed me how he goes about setting up the Tau-P bounds on data to be inverted in order to get the extremal bounds of the model. He spent considerable time explaining how to set up cusp bounds, because these are set in an indirect and conceptually obscure way.

TOM SHIPLEY

Tom uses marine reflection data to study near-ocean-bottom marine sediments. He generally uses only single channel data because it is cheaper to collect and process than multichannel, multicoverage data, and ample for his needs. I spoke to him about problems encountered by John Branson and Keith Lockwood of BMR when trying to stack data collected across deep canyons during the 1982 Bass Basin survey. Because of the long streamer used for the survey, simple stacking of data across regions of extreme topographic and structural relief tends to destroy, rather than reinforce, the signal. He was unable to help me, although he thought that the contractors should be able to stack the data, even if they had to mute out some of the more distant traces. An alternative would be to write an interactive ray tracing program which could work out the corrections to apply to the traces before stack, but this would be time consuming to write and expensive to implement and run on a routine basis.

PAUL HENKART

Paul was lured away from an oil company by Scripps to work on software development. This shows the flexibility of their staffing structure - they are able to create job classifications which can be used to match, or nearly match, the salaries paid in private industry.

The Geological Research Division use the computing facilities of the Institute of Geophysics and Planetary Physics at Scripps for all of their computing, including their seismic computing. They find that this works reasonably well because they do not have large amounts of data to process, although their processing does annoy other

users. They have to pay for their computing time, much as we have to pay for time on the CSIRO computer (they also have to pay for ship time for their field work, even though Scripps owns the ships), and this is a big burden on them.

The computer they use is a PR1ME 750 computer with 900 Mbytes of disc and an array processor. They have various plotters of the Gould/Benson Varian type, but no rasterer, which makes plotting of reflection record sections very slow and expensive. The computer also has numerous terminals and graphics terminals around the campus.

The PR1ME computer has given very good service; it seldom crashes and is very versatile, having 3 Mbyte of core, as well as virtual memory. However, the strength of the operating system is also its weakness. There is no way that a user can control the operating system with privileged programs. Thus the computer is cannot be used for controlling the digitising of data. When double buffering operations are proceeding, the operating system is likely to go away and do its housekeeping when it needs to be writing one of the buffers to disc. PR1ME are aware of the problem; their solution to date has been to sell the user a PR1ME 300 computer to do the digitising separately from the 750 computer.

Because of the problems of funding computing on an another division's computer, the Geological Research Division is trying to buy their own computer. They have bought several small Apollo Domain computers for general computing, and are in the process of buying a larger computer. While they like the reliability of the PR1ME computer, they will probably buy a VAX 11/780 computer. This is because of 'second sourcing' of VAX components. This is where other companies manufacture components which are completely compatible with the VAX computer, and underprice the genuine components from the computer manufacturer. There are many second source components for the VAX but few as yet for the PR1ME. This means that a large VAX installation can be set up for much less than the equivalent PR1ME system.

Paul Henkart has considerable experience with seismic reflection data processing systems. He favours none in particular, except that it is clear that Perkin-Elmer based systems are faster that VAX based systems. This is because the VAX bus is very slow, resulting in slow input/output, and this is very important in I/O dominated processes such as seismic processing. Western Geophysical use VAX based systems in their data processing centres, but

TABLE 1

---BENCHMARK---

The benchmark is a 16384 point FFT of a ramp followed by the inverse FFT. The RMS difference between the inverse and the original ramp is given as RMS err. Two programs, one in real and one in complex arithmetic, are used.

	Wordsize	Processor time SP	RMS err	Processor time CX	RMS err
CDC 7600	60			2.0	2E-10
Cyber 171 opt 1	60			19.5	2E-10
Cyber 171 opt 2	60			15.4	2E-10
Cyber 172 opt 1	60			15.0	2E-10
Cyber 172 opt 2	60			12.0	2E-10
Cyber 173 opt 1	60			11.2	2E-10
Cyber 173 opt 2	60			9.0	2E-10
Cyber 175 opt 1	60			1.9	2E-10
Cyber 175 opt 2	60			1.0	2E-10
Cyber 176 opt 1	60			0.74	2E-10
Cyber 176 opt 2	60			0.53	2E-10
CDC 6600	60			9.2	2E-10
CDC 6400	60			26.0	2E-10
IBM 370/158	32			20.4	2E-04
Burroughs 6700	48			130.0	1E-08
UNIVAC 1108	36			20.0	2E-05
UNIVAC 1100/81	36	5.6	2E-05	6.0	2E-05
INTERDATA 8/32	32	23.0	1E-05	32.0	8E-04
PERKIN ELMER 3240	32	10.3	2E-04	20.5	2E-04
DEC 2040	36			74.0	6E-04
DEC 2050	36			27.0	6E-04
VAX 11/780	32				
DEC FACTORY RESULTS		12.0	2E-04	12.04	2E-04
UCSD 150 PAGE WORK SET		71.4	1E-05	42.4	1E-05
UCSD 600 PAGE WORK SET		15.9	1E-05	13.8	1E-05
HARRIS /6	48	37.0	2E-06	51.0	2E-06
HARRIS /7	48	32.0	2E-06	38.0	2E-06
HARRIS 100	48	29.2	2E-06	37.1	2E-06
HARRIS 500	48	19.5	2E-06	24.4	2E-06
HARRIS 800	48	10.3	2E-06	12.6	2E-06
PRIME 400	32	37.0	8E-04	163.0*	8E-04
PRIME 500	32	28.5	8E-04	172.0*	8E-04
PRIME 750-FTN	32	16.8	8E-04	112.2*	8E-04
PRIME 750-F77	32	16.5	8E-04	20.1	8E-04
S. E. L. -ECL-	32	4.5	2E-04	4.7	2E-04
APOLLO DOMAIN	32	430.2**	8E-04	348.6**	8E-04
DATA GEN. MV8000	32	12.0	1E-04	17.0	1E-04

* The PRIME FTN compiler does not generate inline complex code.

** Without floating point accelerator. The FPA is expected to improve CPU speed about a factor of 5.

they rebuilt the bus for their own needs. This modification is not generally available in any of the commercially available VAX based processing system packages, although the SSL system, which uses a VAX computer in a rather unique configuration is very fast. Tape drives and disc packs are interfaced directly to the array processor, so that data transfers do not have to go through the CPU. The CPU simply directs the operations of the system.

Paul regularly sends computer manufacturing companies a set of data on which he requires the Fast Fourier Transform of a ramp function, and then the inverse FFT. He uses the difference between the input and output, and the time taken as benchmarks for testing the accuracy and speed of the computers. A list of his results is shown in Table 1. Control Data Corporation computers are the most accurate, reflecting their large word size, and are also very fast, as is their reputation for CPU usage. SEL systems are also fast. Some tests that he has performed suggest that the manufacturers results are dependent on the configuration of and operating systems in the computers. Manufacturers may optimise their systems to perform tests such as Paul's in order to make their computers more attractive. When the client who buys a computer configures his computer for general computing needs, he may not get the same results (see, for example, the results from a VAX 11/780).

MARILEE HENRY

Marilee is a student of John Orcutt, and has developed an automatic stacking procedure for producing the Tau-P curve needed for inverse modelling. The method was the brain child of Bob Parker (see later) and is known as slant stacking. It supposedly removes the subjectivity from the process of establishing a Tau-P curve.

She showed me examples of stacks of synthetic and real data. However, the advantages of the method were not immediately obvious. The stacking produces aliasing and this tends to obscure the Tau-P curve. However, with the eye of the faithful, one could be convinced that a curve did lie in the noise.

KEVIN MACKENZIE

Kevin is also a student of John Orcutt, and has just finished some

important work on the way reflection coefficients can be built up from constructive interference in rocks composed of thin laminae. The work arose from studies of thin sediments from the sea bottom, which showed a very strong internal reflection of low frequency energy. When piston cores of the sediments were examined, they had no obvious reflector; rather, they were composed of very thin laminae of unconsolidated sediments with very similar acoustic impedances. Kevin calculated the synthetic seismograms for the sequence using a source wavelet with a frequency near that of the seismic source and found that constructive interference caused the resultant reflected energy to appear as a lower-frequency, large-amplitude arrival. He was able to match the synthetic and real arrivals very well, although he found that the results were very frequency dependent. In a paper to be presented at the 1982 Fall Meeting of the American Geophysical Union, he uses this concept to explain why the refraction method defines an oceanic Moho 1-2 km thick, while vertical reflection profiling shows a strong reflector supposedly implying a sharp Moho. He suggests that the strong reflection may result from a transitional Moho made up of fine laminae of rocks which would appear as a transitional boundary to a refracted wave. When the work is taken further, it may have relevance to studies of the deep continental crust because, unlike the work of the Stanford group, it shows that strong, low frequency reflections can be observed from a higher frequency input into a fairly homogeneous medium.

TOM JORDAN

I spoke to Tom Jordan for only a few minutes. He has worked extensively on the nature, extent and evolution of the sub-crustal lithosphere, and he favours evolutionary models of the lithosphere in which the lithosphere thickens by catastrophic shortening, for example, as is occurring today under Himalayas. Once thickened, the continental lithosphere is less dense than the oceanic lithosphere to great depths, and therefore no longer interacts with it. The continents therefore grow and maintain very thick roots.

KEN CREAGER

Ken is a student of Tom Jordan and is studying the depth extent of subducting slabs by looking at residuals from earthquakes at many azimuths and distances e calculates the residuals by relocating the earthquakes, subtracting the station anomaly, and the Herrin travel-times. He interprets

the data as clear evidence that the slabs may extend to ~800 km depth, and this places limitations on the likely style of mantle convection.

SCRIPPS INSTITUTION OF OCEANOGRAPHY,
INSTITUTE OF GEOPHYSICS AND PLANETARY PHYSICS.

BOB PARKER

Bob is best described as an applied mathematician who can turn his hand to just about any problem in physics. His main interest at the moment is inverse theory, about which he is writing a book. The book is to begin with the basics of inverse theory because, as Bob says, few geophysicists really know anything about inverse theory, no matter what protestations they care to make.

His practical experience with inverse theory includes working with John Orcutt on the Tau-P method, and he has developed a method for one-dimensional magnetotelluric inversion. He has defined a theoretical 'depth of no information' in magnetotelluric inversion below which any model will fit the data without affecting the consistency of the model with the data (Parker, 1982).

He has been working on the magnetic field of spherical basalt pillows observed on the sea bed by deep-tow instruments. For this work, he and several co-workers developed the concept of harmonic splines to fit the data (Shure & others, 1982). He is now applying it in a study of the magnetic field of the Earth's core at the level of the core/mantle boundary. He is hoping to extract the core component from the Magsat data.

CALIFORNIA INSTITUTE OF TECHNOLOGY,
SEISMOLOGICAL LABORATORY

BOB CLAYTON

I went to Caltec to talk to Bob Clayton about seismic reflection processing. He was a student of Claerbout at Stanford, and had been recommended to me by Prof. Anton Hales of the Research School of Earth Sciences at the Australian National University as a capable seismologist with practible ability in seismic reflection processing.

Seismic reflection processing is no longer his main preoccupation. He has teaching commitments and graduate students to supervise, but he still keeps his hand in at reflection processing. At the time of my visit, he was working on some 1024-channel sign-bit data from the Perth Basin, Western Australia.

He runs several PDP-11 and VAX 11/780 computers, and a PR1ME 750. He considered second sourcing as the most important factor in choosing a computer for processing. For example, because of second sourcing of plug-in memory for his VAX 11/780, 1 Mbyte of core costs about $3000. Second sourcing of PR1ME components and peripherals is, as yet, limited, and 1 Mbyte of memory for the PR1ME costs about $30 000, or ten times the cost for the VAX.

He also suggested that we pay particular attention to which operating system we choose for our processing computer. He has a VMS operating system in his VAX. This is excellent for academic-style programming, where a large number of computer programs are written and compiled. However, the penalty when such a system is used for routine processing of large amounts af data is a slow through-put. Many of the commercially available seismic processing systems based on the VAX computers use a different operating system, with a subsequent faster throughput, but the operating systems have limited program compilation capabilities and would be restrictive if we wanted to develop our own processing techniques.

Clayton made a third suggestion. We should look ahead to what sort of field operations will be conducted in the future. 1024-channel sign-bit field recorders are already available, and several companies are developing 1024-channel full-bit recording systems. Although predicting what computing facilities will be required to process such vast amounts of data is very hard, we should try to purchase a system that appears to be flexible enough to modify and cope, at least in a small way, with such data quantities.

Clayton's major interest at present is in the structure of the upper mantle, and he has several students working on different aspects. He showed me a composite record section that had just been produced (but not yet interpreted) in which he had compiled the recordings of teleseisms originating in South America and recorded across the southern Californian seismic network. The traces had still to be corrected for the effects of

station residuals and the effects of the different sources, but several features were obvious. Reflections from the 400 km discontinuity were very clear as later arrivals. First arrival slownesses changed near 29 and 38 degrees, due to discontinuities in the mantle at depths of 770 and 980 km (approximately) first observed by Muirhead & Hales (1980) to the north of Australia.

I could see clear evidence for a discontinuity near 200 km depth in the record section, but most of the workers at Caltec, with the exception of Don Anderson, do not believe that the 200 km discontinuity exists.

MARIANNE WALCK

Marianne is a graduate student of Clayton, and is studying the detailed structure of the mantle to about 600 km depth by using synthetic seismogram matching of observed teleseismic arrivals. Her starting model is based on the inversion of travel-time data by the wave field continuation method of Clayton & McMechan (1981). A interesting consequence of her use of this method, which is supposed to remove the subjectivity from the interpretion when establishing the starting model, is that her model has a seismic discontinuity at 200 km depth. Marianne does not believe in the 200 km discontinuity, but no realistic modification to her data will remove it from the model.

TOM HEARN

Tom is also a student of Clayton, and he is studying crustal structure and Pn anisotropy. He is using Pn data from earthquakes which occurred within and were recorded by the southern California seismic network. He has clear evidence of anisotropy and also changes in the isotropic component of the Pn velocity laterally across the region. His results compare favourably with those of Vetter & Minster (1981), who coincidentally also made their study at Caltec. Hearn is presently writing up his results.

DON ANDERSON

I spoke only briefly with Anderson about the nature of the sub-crustal lithosphere. He believes that the Ringwood pyrolite model of the upper mantle is wrong, and that the uppermost mantle above 200 km is olivine rich and therefore capable of exhibiting anisotropy in order to explain the high velocities and discontinuities now being observed, eg. by Hirn & others

(1973) in Europe, Mereu & others (1977) in Canada and Drummond (in press) in northwest Australia. Below the 200 km discontinuity, the upper mantle is composed mainly of eclogite, with seismic velocities dominated by the presence of garnet, which is isotropic.

3. THE INTERNATIONAL SYMPOSIUM ON ARCHAEAN AND EARLY PROTEROZOIC GEOLOGIC EVOLUTION AND METALLOGENESIS (ISAP).

The ISAP was held in Brazil from 3 to 11 September, 1982. Excursions were held from 3 to 7 September, and the scientific sessions from 8 to 11 September. The ISAP was sponsored by the Department of Mines and Energy, Bahia State, the Brazilian Geological Society, the Brazilian National Council of Scientific and Technological Development, the Brazilian Academy of Science and the Inter-Union Commission on the Lithosphere. About half of the 292 registrants were Brazilian, although many of the non-Brazilians worked for exploration companies operating in Brazil. Six Australians attended (Sue Golding and spouse from the University of Queensland, Katz from the University of New South Wales, Groves from the University of Western Australia, Lambert from Baas Becking, Canberra, and myself).

The ISAP was the first international symposium in the earth sciences held in Bahia State, and consequently was a little disorganised at the beginning. This was especially so with the audio-visual equipment. All papers were presented in English and their simultaneous translation into Portugese was also a burden on the organisers, and especially the speakers, who were initially expected to adhere closely to their manuscripts in order to help the interpreters. The style of presentation adopted by early Brazilian speakers, who sat behind a desk and read their manuscripts, added to the difficulty of concentrating on the material presented. However, as more of the invited and more experienced delegates gave their papers in the form of seminars, the style of the meeting became less formal, and the standard of the presentations from all participants improved. The meeting ended with an air of success.

Lectures began at 08.00 each day, and generally ended around 17.00. At variance with most symposia, lectures were given in sessions of 3 to 4 hours with a single discussion at the end of each session. I felt that this limited the amount of discussion on each paper because of the long delay which often occurred between the presentation of the paper and the discussion period at the end. Private talks with the authors of the papers that I found

interesting were often more fruitful.

Sixty papers were presented, and a list of the titles and authors who provided abstracts is given in Appendix 2. Substitute papers were given for eight of these when the authors failed to register. The list of extra titles is added at the end of the appendix.

Invited speakers presented their thoughts in the morning sessions. Most invited speakers were given one hour, which I found was too long and resulted in several tedious presentations, and they generally gave review papers. Two parallel sessions, one dealing with regional geologic evolution and the other with either metallogenesis or petrology and geochemistry, were held in the afternoons. This meant that I was unable to hear half of the afternoon presentations, so I went to the sessions on geologic evolution which were more relevant to my current interests.

The volume of abstracts of the papers presented has been lodged in the BMR library (call number 551.71/.72 INT, in two parts) and also includes the excursion guides. The geological map of Brazil and offshore areas at 1:2 500 000 scale was released at the symposium, and is also in the library (lodged in the map cabinet, call number GEO), as are the metallogenic map of Bahia State at 1:1 000 000 scale (map cabinet, call number MET) and the proceedings (in Portugese) of a symposium on the Sao Francisco Craton and its marginal belts held in Salvador in 1979 (call number 551.24 SYM). The papers were originally to be published in an international journal, but the Brazilian organisers felt that the international reputation of Brazilian geology would benefit more if they were published by the Brazilian Geological Congress. The proceedings were reportedly in press at the time of the symposium and hopefully will be available soon.

The subject matter of the papers can be split into several categories. They are (i) general aspects of geological evolution in the Archaean and early Proterozoic, (ii) general aspects of metallogenic processes in the Archaean and Early Proterozoic, (iii) geological, geochemical, geophysical and geochronological studies of specific regions of the Precambrian, and (iv) studies of specific ore bodies. Categories 1 and 2 were almost exclusively the domain of the invited speakers, and generally contained little new information but sometimes contained new interpretations of Precambrian crustal evolution or metallogenesis. However, the way papers were organised into sessions makes a summary of the papers difficult.

No attempt seemed to have been made to have papers dealing with the same topic in the same session. Thus, papers on geological evolution were scheduled on the first, third and fourth mornings, and on each of these mornings were mixed with papers on aspects of metallogenesis. This made comparison of some of the conclusions difficult, and discussion limited.

Many of the papers dealing with the metallogenesis or evolution of specific regions contained new, interesting and useful information, but few had any comment on the relevance of this information to general models of Precambrian crustal evolution. Consequently, many of these papers will not be mentioned in the following discussion dealing with the content of the conference papers. The information can be gleaned from the abstracts of the papers in full when they are published.

Many of the papers studied the way continents may have grown in the Precambrian, and most favoured models in which continents grew by lateral accretion. Moorbath, on the basis of radiogenic isotope analyses, favoured the hypothesis that continents grow with time as the crust irreversibly differentiates from the mantle. Kroner also preferred a unidirectional pattern of global crustal evolution. In his model, greenstone belts formed in incipient rifts within continental plates, with crustal growth around the edges of plates. Plate tectonics probably occurred in the Precambrian, but with smaller and faster mantle convection cells. Tarney, in a paper with Weaver and Windley, tried to explain the generation of granulite terrains by the subduction of accretionary wedges at continental margins. Following metamorphism, the wedges would be uplifted in a compressive regime to form granulite terrains. Greenstone belts form in a tensional back-arc environment. He drew attention to modern day analogues in the Alps and in the Andes in Chile.

Van Schmus discussed the evolution of the Archaean/early Proterozoic transition in the United States and concluded that the southern margin of the Archaean Craton of North America was the location of extensive lateral accretion in the early Proterozoic.

Anhaeusser was to give a paper on the evolution of greenstone belts, but gave instead a seminar on the geology of the Barberton Mountain Land. This was probably of considerable benefit to those of us who have not visited the area, but contributed nothing to the discussion of early Precambrian

crustal evolution, and especially the origin of greenstone belts about which he had originally elected to speak.

Several papers dealt with intraplate activity. Hargraves looked at rates of polar wander in the Precambrian, and concluded that some plates wandered separately as microcontinents, while others accreted to form larger continents. Looking at the elements that originally comprised the African and South American parts of Gondwanaland, he concluded that large scale transcurrent movements, with only minor openings and closings of oceans, may have played a more important part in Precambrian tectonics than they do today. Barton looked at the geochronology and geochemistry of rocks from the Limpopo Belt and Kaapvaal Craton and concluded that while continents formed from accreted pieces of continental crust, the accreted pieces continued to evolve separately and now show the geochronological and geochemical signatures of separate evolutionary histories.

The paper which I presented dealt with the uniformity of crustal composition at any depth in the Pilbara Craton, and the constraints that seismic data could place on the likely chemical composition in the lower crust in the Pilbara Craton. I tried to relate my results to likely differences in the tectonism between the Archaean and younger provinces. The paper I read for Finlayson looked at changes in the velocity signature of the crust across the North Australian Craton. Eriksson compared and contrasted sedimentation styles in the Kaapvaal Craton and the Pilbara Block.

Several papers (Lambert, Maissoneuve) dealt with the early geobiological evolution of the earth, and especially with the composition of the Precambrian seas.

Two papers were presented on the early Precambrian of China (Cheng Yugi and others), but were geological reviews rather than studies of geological evolution.

Goodwin presented a excellent paper on the distribution and style of Precambrian banded iron formations. Banded iron formations have formed throughout geological time and are distributed fairly evenly geographically (they occur in all Archaean cratons). However, about 90% were formed between 2000 and 2500 m.y. ago and when plotted on a Gondwana reconstruction

lie along a zone which snakes through the interior of the reconstruction, generally within but parallel to the edges of the new continents which formed by the breakup of Gondwanaland. Throughout time, the bulk composition of banded iron formations has remained remarkably constant, although there are sometimes local concentrations in some elements, eg. S, P, Al, Ca and Mn. Goodwin offered no strong arguments for or against any mechanisms of formation, and admitted to no certain knowledge of the source of the iron. He was very interested in my calculations, based on seismic models and the consideration of isostatic constraints, that sufficient mass (presumably very iron rich) has been removed from the upper mantle under the Pilbara Craton to account for the entire volume of banded iron formations and basic volcanics of the Hamersley Basin. I left it to him to work out the transport and deposition mechanisms.

Groves presented a paper on the origin of banded iron formations in Australia, as well as a more general p.aper on the evolution and metallogeny of Australia, in which he concentrated mainly on the mineral deposits of the Western Australian Pilbara and Yilgarn Blocks. Viljoen discussed the nature of gold mineralisation in South Africa and Zimbabwe, and Hutchinson gave a general review of base metal sulphide deposits in the Precambrian.

Very few papers discussing geophysical results were presented. They filled only part of one afternoon session. Apart from the two I presented, only three others were given. Hamza tried to calculate the Archaean geothermal gradient in South America. He gave rigorous attention to the theory involved, but the actual heat flow data presented were scarce, the measurements of thermal conductivity in near-surface rocks even more scarce, and the distribution of heat producing elements was assumed, resulting in a geothermal gradient for the Archaean that must, at best, be tenuous. Haralyi & Hasui's paper on the gravity field of Brazil was generally qualitative, discussing trends and styles of anomalies with the results of their two-dimensional quantitative interpretation presented without a great amount of confusing detail. Thus the paper would have had considerable appeal to people working on Brazilian tectonics. The Brazilians have no seismic models to provide control on their gravity modelling, so that their crustal thicknesses derived from gravity data must be taken as first order approximations only.

De Beer's paper used gravity and electrical sounding techniques to study the structure and depth extent of the Murchison Greenstone Belt in

South Africa. The gravity models seemed very complicated and may even have been over-interpreted, but they did have the added constraint of the results of electrical sounding. The thickness of the greenstone belt was set at 7 km.

Obviously, I will have gained most from the papers dealing with subjects which are close to my own present interests, and about which I am therefore most familiar. People with other interests may have gained completely different opinions of the content of the symposium. Fortunately, the papers are to be published in full, and this will allow me, and others who are interested but were not at the symposium, to review the papers at leisure and judge them anew.

4. WORKING GROUP MEETINGS HELD IN CONJUNCTION WITH THE ISAP

Working Groups 3 (Proterozoic Lithospheric Evolution) and 4 (the Archaean Lithosphere) of the International Lithosphere Program, and Working Group 91 (Precambrian Metallogeny) of the International Geological Correlation Program (IGCP) met at the ISAP. I did not attend the IGCP meeting, but a copy of the minutes is included as Appendix 3.

Ray Price, chairman of the Inter-Union Commission of the Lithosphere Bureau, attended the meetings, and set out the conditions under which the ICL would sponsor scientific meetings. These are set out in Appendix 4, and generally relate to the provision to the ICL of copies of the proceedings and publications, as well as acknowledgement of the ICL sponsorships in any publications arising from such meetings. Chairman Price also clarified the structure of the working groups. Each working group consists of members, nominated by the ICL Bureau, and corresponding members, who are often nominated from outside the Bureau. Coordinating committees have been set up to coordinate the interaction between the working groups.

The ICL does not have sufficient funding to financially support any scientific work. It can provide some financial support to allow members of the working groups to attend meetings supported by the working groups; it will not give financial support to corresponding members. However, ICL working groups can endorse projects which are deemed to fall within their areas of interest, and this endorsement can be used by the project organisers as evidence of the international significance of their project when they apply to their funding agencies. However, endorsement will only be given

to multidisciplinary projects. Thus a study which uses only geology, or geophysics, or geochemistry, will not get official ICL support.

Before the meeting, the chairman of WG 3 had asked participants to provide lists of projects which fell within the auspices of WG 3, being undertaken in their own countries, and the chairman of WG 4 asked for similar lists at the meeting. I took with me to the meeting a folio containing a summary of activities proposed for Australia, with which I included a copy of the article prepared by M.W. McElhinny, Chairman of the Australian National Committee for the Lithosphere Program within the Australian Academy of Science (McElhinny, 1982), and a set of abstracts of the papers presented at a workshop meeting held in Canberra in May, 1982 to review proposals for Lithosphere transect studies and to establish the ACORP project. The Australian effort proved to be the most comprehensive lithospheric programme yet devised, and Price borrowed a copy of my summary so that he could show it as an example of the sort of programme that the ICL considers ideal.

Working Groups 3 and 4 met separately on one evening. I attended the WG 3 meeting (the minutes are in Appendix 5), and David Groves of the University of Western Australia attended the WG 4 meeting (Appendix 6). The following evening, the two working groups held a joint meeting to discuss matters of common interest (Minutes, Appendix 7).

As the details of the working group meetings are given in the Appendices, summaries of the business discussed will suffice here.

Working Group 3 - Proterozoic Lithospheric Evolution (Appendix 5)

Future Business Meetings:

1983 To be held in China in September at an international symposium on Precambrian crustal evolution, in cooperation with WG 4, and IGCP Project 92 and with the IUGS Commission on Tectonics. The details of the international symposium are still sketchy, but should be clear by early in 1983 so that interested people can prepare submissions for funding. The working group, with WG 4, is to hold a symposium on tectonic boundaries in the Precambrian.

People presenting papers it IUGG in Hamburg in August, 1983, are encouraged to indicate if their papers fall within the auspices of the

WG 3 mandate.

1984 The 1984 business meeting is to be held at the IGC in Moscow. WG 3 is to sponsor Congress Symposium S.05.2.3 (Granulitic problems, Precambrian ophiolites and the genesis of grey gneisses). Further details in the minutes.

1985 The Brazil meeting did not need to look beyond 1984 in setting up future business meeting venues, but I mentioned that Australia was keen to host a meeting. However, it seems that, wherever possible, business meetings are to be appended to international symposia to allow access to other sources of funding for travel costs, so that we may not get the 1985 meeting if such a symposium should eventuate. I mentioned that the Australian Academy of Science had some funds, albeit very limited, to bring people to Australia for suitable meetings.

Working Group Sponsorships:

(i) Meetings - A symposium in Lusaka, Zambia, in April, 1983, is to receive WG 3 sponsorship if it is requested (details, Appendix 8).

(ii) Projects:

(a) In keeping with the ICL philosophy of supporting worthy multidisciplinary projects, WG 3 is to support the work of A.C. Tobi of the Netherlands in his bid for funding from the United Nations to study the Proterozoic evolution of southern Norway, and to make comparisons with the Grenville and Superior Provinces on the other side of the Atlantic Ocean.

(b) Considerable time was spent discussing whether the working group should nominate general topics for research, or whether it should suggest specific research projects. A list of specific research topics drawn up by Kroner and A.A. Beus is included in Appendix 5. The subject was left until the combined meeting with WG 4.

Working Group 4 - The Archaean Lithosphere (Appendix 6)

Future Business Meetings:

The 1983 and 1984 business meetings of WG 4 will be held with WG 3 in China and Moscow, respectively. Details are in the minutes in

Appendix 6. IGCP project 92 is having a meeting in Glasgow in 1983, to be followed by an 8 day field trip. This may be an alternative venue for the 1983 business meeting if the China meeting does not eventuate.

Groves intimated that the Western Australians are contemplating a third International Symposium in Perth in 1990, and would like WG 4 sponsorship. No doubt a business meeting would be held at the time.

Working Group Sponsorships:

Working Group 4 did not seem to be as far advanced in its organisation as WG 3, and was only at the stage of calling for a list from each country of active projects which fall within its mandate. The group was not very concerned about calling for a list of projects which should be pursued in the future, feeling that projects would eventuate as a natural consequence of the issues raised at international symposia.

Combined WG 3 and WG 4 meeting.

The combined working groups accepted the Chinese invitation to support their September, 1983 meeting and decided to hold their 1983 business meeting at the China symposium. Considerable time was then spent discussing the topic for a symposium for the China meeting, and whether a field excursion could be held. The outcome of these discussions is in the minutes (Appendix (Appendix 7).

A plea from Jack Oliver of Cornell University for requests for COCORP work outside the United States led to a long discussion on the types of projects the working groups should support, and at what level. Oliver would like to make a study of the major crustal features around the world (Oliver, 1982), but needs requests to be made to him by organisations such as the ICL in order for him to justify asking for funding for projects outside the United States. It was decided that the working groups were not in a position to recommend or request specific projects in specific areas. This could easily be interpreted as interference in the internal running of the scientific programmes of the countries involved. Rather, people like Oliver should encourage scientists in the countries concerned to put firm proposals to their own national committees on the lithosphere, who could then call for official ICL recommendations for financial support.

This is one way in which the ICL could recommend support for work in developing countries.

5. SUMMARY AND CONCLUSIONS

(i) Computing Systems.

All of the US government and university groups that I visited have or are purcahsing large, general-purpose computers for their in-house computing needs. This allows them considerable flexibility in the types of research that they can undertake based on heavy computing requirements. If BMR is to match them on a computing power per scientist basis, we would have to buy several large systems of the VAX 11/780 or PR1ME 750 type. This is independent of our need for an in-house seismic processing system.

US institutions consider second-sourcing the most important feature of any computer purchased, because it can ultimately lead to a much cheaper system. Maintenance of second-source components is very reliable in the US, but this is not so in Australia. Therefore, when buying our seismic processing system, we should look for (i) flexibility of the software, especially the operating system software, and (ii) the ability to expand the system to meet future computing demands.

(ii) Seismic Refraction Experiments

The USGS is doing most of the seismic refraction studies of the crust in the western US, although Caltec is doing some work with earthquake studies. However, the studies are still done on an opportunity basis, and neither institution seems to have a long term goal in its programme - for example, detailed study of the evolution and present-day tectonics in the western US.

US scientists place a lot of faith in linear inversion of seismic data, thus hoping to remove the subjectivity from the interpretation, and at the same time placing extremal bounds on their models. However, the extremal bounds set by the inversion methods available to date are usually very generous - in many cases they are so broad that sharp discontinuities apparent in the data are not required in the model. Perhaps the inclusion of amplitude data in the inversion sometime in the future will further restrict the bounds of the model.

(iii) The ISAP

The feature which I found most interesting in the models of crustal evolution presented at the ISAP was that most suggested that the Archaean crust formed by lateral accretion. All of the models differed in detail, and this usually meant that there was no consensus reached among the delegates regarding the most likely evolutionary model. All of the delegates were so engrossed in their own techniques that they were becoming bogged down in the details. What is needed is a carefully coordinated multidisciplinary study of early Precambrian crustal evolution. For this reason, the types of transects proposed by the Australian ILP committee should prove very worthwhile. What is especially needed in the Archaean studies is much more input from geophysics to define the nature of the lower crust and uppermost mantle. Such input is available in studies of younger regions around the world, but very little work has been done in the Archaean. Australia is very well qualified to make a significant contribution to studies of Archaean crustal evolution because of our vast Archaean areas, the geological detail in which we know them, and the BMR's ability to undertake multifaceted geophysical studies across them.

(iv) The International Lithosphere Program

In many respects, the ILP is still getting under way in many countries. However, Australia more than any other country is well on the way to achieving its objectives.

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APPENDIX 1.

OVERSEAS VISIT - B.J. DRUMMOND

Detailed Itinerary

Date	From	To	Airline	Flight	Depart	Arrive	Hotel	
1 Sept	Canberra	Sydney	TAA	406	12.40	13.15		
	Sydney	San Francisco	QANTAS	QF3	20.00	18.20*	Mermaid Inn 727 El Camina Real Menlo Park California 94025 Tel (415) 323-9481	*Arrive 1 Sept
5 Sept	San Francisco	Miami	Pan Am	60	08.00	16.17		
	Miami	Salvador	Varig	Rg 807	19.00	08.35*	Bahia Othon Palace Hotel Av. Presidente Vargas, 2456 40.000-Salvador- Bahia-Brazil Tel (071) 247-1044 Telex (071) 1217	*Arrive 6 Sept
12 Sept	Salvador	Rio DeJaneiro	Varig	Rg 343	18.00	19.50		
	Rio DeJaneiro	Houston	Pan Am	440	22.30	09.25*		*Arrive 13 Sept
13 Sept	Houston	San Diego	Pan Am	921	10.15	11.12	Shell Beach Hotel Tel (714) 4594307	
15 Sept	San Diego	Los Angeles	PSA	PS285	11.55	12.30	Huntington Hotel Pasadena	
16 Sept	Los Angeles	Sydney	QANTAS	QF12	21.00	08.10*		*Arrive 18 Sept
18 Sept	Sydney	Canberra	Ansett	AN361	13.45	14.25		

Overseas Visit, B.J. Drummond

Contacts in the US and Brazil

1 September	Dr J.H. Dieterich Director, Office of Earthquake Studies, United States Geological Survey, 345 Middlefield Road, MENLO PARK California 94025 USA
2 September	Dr J. Claerbout or Dr George Thompson Department of Geophysics, School of Earth Sciences, Stanford University, STANFORD California 94305
6-11 September	Augusto J. Pedreira ISAP Coordinator CPRM - Rua Barros Falcao, 21 40.000 SALVADOR Bahia BRAZIL
13-14 September	Dr John Orcutt (on the 13th only) Geological Research Division Scripps Institution of Oceanography, LA JOLLA California 92093 USA or Dr Robert L. Parker Institute of Geophysics and Planetary Physics, Scripps Institution of Oceanography, LA JOLLA California 92093 USA
16 September	Dr Bob Clayton Seismological Laboratory California Institute of Technology, PASADENA California 91125 USA

APPENDIX 2

ABSTRACTS

1 – GENERAL GEOLOGIC EVOLUTION

2 – REGIONAL GEOLOGIC EVOLUTION

3 – PETROLOGY AND GEOCHEMISTRY

4 – METALLOGENESIS

Replacement Papers

Paper Number	Replaced by
1.	J. MAISONNEUVE - The composition of Precambrian ocean waters
2.	A. BERNASCONI - The Archaean terranes of central eastern Brazil - reappraisal.
3.	N.T. ARNDT - Physical properties of komatiites and some words about Ni deposits and Archaean plate tectonics.
4.	E. KADIO - Archaean and lower Proterozoic of the Ivory Coast: Geology and Metallogenesis.
5.	Cancelled
6.	D.I. Groves - Epigenetic origin for Archaean BIF-hosted Au deposits: evidence from Western Australia.
7.	P.A. SNOWDEN - Witwatersrand tectonics and its significance in the late Archaean evolution of Southern Africa. Replaces a paper by Shuldiner which does not appear in the list of abstracts.

APPENDIX 3.

INTERNATIONAL SYMPOSIUM ON ARCHEAN AND PROTEROZOIC SALVADOR

EARLY GEOLOGIC EVOLUTION AND METALLOGENESIS BRAZIL, 1982

MINUTES OF WORKING GROUP IGCP PROJECT 91

Salvador, Brazil - 10.09.1982

IGCP PROJECT 91 (Precambrian Metallogeny)

Meeting on 10th September, 1982

Place ISAP Meeting, Salvador, Brazil

Present Members G.Gaál, D. Groves and 6 participants of ISAP:

Prof. U.G. Cordani	Brazil
Prof. A. Kroner	FRG
Dr. I.B. Lambert	Australia
Dr. M.M. Marinho	Brazil
Dr. A.J. Pedreira	Brazil
Dr. R.I. Price	Canada

1§ David Groves opened the meeting and expressed the deep regret felt by the members of the death of the leader of IGCP project 91, Academician A.V. Sidorenko.

2§ The Brazilian representatives were welcomed and thanked for the excellent organization of the conference and field trips of ISAP in Brazil.

3§ The Brazilian representatives regreted the absence of Prof. V. Kazansky and the other Soviet delegates in ISAP and project 91 meeting.

4§ Recent activities:

- Members of project 91 participated in the joint project 91/181 Nickel Field Conference III in Western Australia in May-June 1981. Several publications resulted from this meeting.
- Project 91 and IAGOD arranged a joint conference in Tbilisi, U.S.S.R. with field trips to various mines in the U.S.S.R. in August, 1982.
- The members of project 91 participated actively in the ISAP meeting and presented the following papers:

  Groves, D.: Archean epigenetic banded iron formation-hosted gold deposits: evidence from Western Australia.

  Gaál, G.: Proterozoic nickel metallogeny and related tectonics in the Baltic Shield.

  Groves, D.: The Archean and Earliest Proterozoic evolution and metallogeny of Australia.

5§ Planned activities in 1982-84:

- G. Gaál informed that projects 91/160 will arrange a joint meeting with field trips on Precambrian exogenic processes and related metallogeny in Finland in August 1983.
- This meeting endorsed a recommendation from Nickel Field Conference III for a field trip to Norilsk, U.S.S.R. in conjunction with IGC in Moscow in 1984.

6§ Symposium "Metallogeny of the Precambrian" during the 27th session of IGC in Moscow in August 1984.

Members endorsed the organization of this Symposium by Prof. V. Kazansky and hoped for active participation from the members. The Brazilian participants expressed their interest in the symposium and it was emphasized that a contribution of the relatively unknown metallogeny of Brazil would be an important contribution to the symposium. Participation from other developing countries should be actively sought to continue the good record of the project in this respect.

7§ Administrative questions

There was unanimous agreement that Prof. V. Kazansky be asked to assume permanent leadership of IGCP project 91, in view of his excellent work in the realization of aims of the project from its inception.

G. Gaál
Secretary of the Working Group Meeting

APPENDIX 4

Resolution on ICL Sponsorship of Scientific Meetings

(from the Minutes of the ICL Bureau Meeting, December 1980)

Sponsorship by the Commission of any symposium, workshop, or other scientific meeting will be granted only on the following conditions:

1. The proceedings or other publication arising from the meeting will be identified as a publication of the International Lithosphere Program as follows: either by (a) a Lithosphere Program Report Number and the lithosphere Program logo on the cover of the publication; or else (b) the Lithosphere Program logo on the cover and the following statement either on the cover or on the title page of the publication: "Publication Number _____ of the International Lithosphere Program."

2. The meeting organizers agree to provide the Commission, free of charge, a number of copies of the meeting proceedings. This number will normally be 50; deviations will be considered in special cases.

3. The meeting organizers agree to submit, within a reasonable time (to be specified by the Secretary-General) after the end of the meeting, a summary article for publication in the ICL Newsletter and in general-interest magazines such as Episodes, EOS, Geotimes, etc.

The organizers of symposia and other meetings sponsored by the Commission are expected to obtain support for publications from national or other sources.

APPENDIX 5

INTER-UNION COMMISSION ON THE LITHOSPHERE

Working Group 3 (Proterozoic Lithospheric Evolution)

Business Meeting No. 1
Othon Palace Hotel, Salvador, Bahia
9 and 10 September 1982

MINUTES

The meeting was called to order by Acting Chairman Kröner at 20.20 hours on 9 September 1982 in the Itapoan Room of the Othon Palace Hotel, Salvador. Present were Kröner, B. Drummond (representing R.W.R. Rutland), E. Barton (representing B.J.V. Botha) J. de Beer, N.G.K. Nair, R. Van Schmus, B.B. Brito-Neves, G. Gaál. As guests: A.C. Tobi, Netherlands and E.Wernick, Brazil (as correspondent of CC-4). President Price joined the meeting at 20.30 hours and Bureau Member Cordani also attended part of the meeting.

1. Kröner opens the meeting by welcoming members, correspondents and guests. He reports on the tragic death of Chairman Sidorenko and, as a mark of respect, reads from a letter on Sidorenko's career and achievements received from A.A. Beus.

2. Participants introduce each other and give a short summary of their scientific activities and interests.

3. Kröner reports on the present membership status, and a short discussion follows on policy regarding appointment of future correspondents. It is stressed that new appointments should be made preferentially from countries not yet considered in the WG rather than from those already well represented. It is agreed that N. Sozinov, USSR, originally proposed by Chairman Sidorenko and considered by the Bureau, should become a correspondent.
   A.C. Tobi, Netherlands, requests association with the WG on account of his co-ordinating role in a multinational and multidisciplinary research project on the Proterozoic evolution of Southern Norway. He also requests WG support for a NATO Study Institute on this subject, to be held in 1984. This is accepted and Dr. Tobi is nominated for correspondentship. Further discussion on additional correspondents is postponed to the next meeting.

4. Bureau chairman Price gives a short overwiew on finances of the ICL and on the philosophy of WG and CC activities.

5. Kröner reports on a symposium "Proterozoic 83" to be held in Lusaka, Zambia, 11-13 April, 1983 and organized by the Geological Society of Zambia. It is agreed that individuals should be encouraged to participate but that no meeting would be held at the occassion of this symposium. If sponsorship is sought by the organizers this will be proposed to the Bureau.

6. Participation in the IUGG Hamburg meeting in 1983 in discussed. It is agreed that WG 3 will <u>not</u> organize a scientific symposium, but that individuals are encouraged to participate and identify their contributions as part of WG 3 activities. If several WG members come, an unofficial meeting may be held.

7. Kröner reports on the possibility of holding a scientific symposium on Precambrian crustal evolution in China in 1983, in cooperation with WG 4, with IGCP Project 92 and with the IUGS Commission on Tectonics. After some discussion such a meeting is favoured by the WG, but further discussion is postponed to the following day.

8. Kröner reports on preparations for the IGG in Moscow in 1984 and the fact, that the ICL WG's and CC's are supposed to hold official business meetings at this occasion. He also reports that the Congress Symposium S.05.2.3. (Granulitic problems, Precambrian ophiolites and the genesis of grey gneisses) is now con-

sidered as the official symposium of WG 3 and will take place in collaboration with sections tectonics, petrology, geochemistry and planetology. Some 6 participants my be selected by Co-Convener Kröner, the others will be proposed by the USSR. Interest in this symposium is expressed by Nair, India and Wernick, Brazil. Chairman Price suggests that the WG should also consider to participate in some of the symposia organized by other WG's.

Kröner suggests that WG's 3 and 4 should request a field trip to the deep hole site near Petsamo, Karelia and the neighbouring Kola terrain during the IGC in Moscow. This is strongly supported by those present and Kröner is requested to make this proposal to the ICL Bureau.

9. Drummond indicates that R.W.R. Rutland may invite the WG to hold a meeting in Australia in 1985 at the occasion of an international meeting in Canberra. This is noted with considerable interest and Australia is provisionally set aside for an official meeting in 1985.

10. Activities of WG 3. Kröner reports on a meeting with A.A. Beus in Moscow in 1981 where a list of specific research topics, thought relevant for Proterozoic Lithospheric Evolution, was drawn up and distributed to members and correspondents for their comments. Kröner had not received any comments, those received by the late Acad. Sidorenko were not available at the meeting. Price emphasizes that the WG should formulate its research proposals in such a way that geophysicists feel invited to participate and that truly multidisciplinary projects are created.

Kröner distributes a listing of summaries of Lithosphere Project activities as relates to WG 3, arranged by countries. A list of research topics is appended.

The first part of the meeting ends at 22.30 hours.

Proposed research topics Working Group 3 Lithosphere Project

1. Evolution of Proterozoic mobile belts
2. Proterozoic palaeomagnetism and reconstruction of Proterozoic plate motion
3. Growth and evolution of the Proterozoic continental crust and subcrustal lithosphere
4. Chemical composition and differentiation of the Proterozoic lithosphere
5. Proterozoic metallogeny and tectonic regimes
6. Thermal evolution of the Proterozoic lithosphere
7. Thermodynamics of Proterozoic crust and mantle
8. Proterozoic ophiolites and their tectonic settings
9. Definition of Proterozoic tectonic provinces by geological, geophysical, geochronological and geochemical techniques
10. Surface processes and evolution of the Proterozoic atmospherr
11. Isotopic investigations of Proterozoic crust-forming processes
12. Proterozoic magmatic and metamorphic processes

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APPENDIX 6.

Minutes of: Meeting of W.G.4 at I.S.A.P. Salvador, Brazil
8:00 p.m., Wednesday, 8th September 1982

The first formal meeting of the Archean Lithosphere WG4 was held in conjunction with the International Symposium on Archean and early Proterozoic.

Members/corresponding members present:

A. Baer, R. Hargraves (Acting Chairman), S. Moorbath, Shen Qihan, B. H. Schorscher, M. Viljoen, N. Arndt, J. Barton, K. Eriksson, D. Groves, M. Naqvi, J. Tarney.

Visitors (part-time): Bai Jin, A. Goodwin, R. Price, U. Cordani.

1. Goals for the Working Group:

Hargraves suggested that general goals of working group, as per previous letter from B. Windley, might be described as:

a) To foster communication and synthesis of existing research
b) To stimulate more interdisciplinary and international research
c) To bring together earth scientists of many disciplines to encourage cross-fertilization of ideas.

To these ends, he considered that it would be useful to attempt to compile a listing of what research related to Archean problems was currently being done around the world. The value of such a list, and the comprehensiveness of coverage desirable, or required, was discussed.

In addition, Hargraves proposed that members should be asked to submit what they perceive as major problems in Archean geoscience. Distribution of this list might be of wide interest, and at least would serve as a basis for selecting and defining a restricted number of specific major problems appropriate for interdisciplinary, and international, research focus.

Eriksson suggested that such a broad listing of Archean problems had emerged from the Early Crustal Genesis Workshop organized by the Lunar Planetary Institute and held in Virginia in November, 1981. Distribution of this to all members would be appropriate and might facilitate selection and definition of the major problems to be championed by the W.G. Hargraves agreed to distribute this information as soon as possible. Both Naqvi and Groves urged that these "problems" should be defined as major projects, to be officially sponsored and actively promoted by the working group. After further discussion it was proposed by Baer, seconded by Viljoen, and unanimously approved that:

All W. G. members are requested to provide a listing of ongoing Archean research in their respective countries and/or discipline.

All W.G. members are requested to provide a listing - long or short - of what they perceive as fundamental problems pertaining to the Archean.

This information should be provided to the Chairman by the end of October.

International Data Banks

In correspondence to the Chairman Dr. Grachev had suggested that the W.G.4 might promote the establishment of an International Data Bank for geochemistry of Archean Rocks.

In discussion, Prof. Tarney expressed reservations about the possibility of W.G.4 attempting this in view of the magnitude, and logistical complexity of such a task.

Dr. Barton felt that to some extent such data banks were already available (e.g. U.S.G.S.) and that those interested could readily obtain information from these agencies.

No specific action was taken.

3. Symposia Topic for I.G.C. 1984

Prof. Price had indicated that under pressure of schedules, the Commission had reserved one Symposium session for each W.G. at the IGC, 1984 in Moscow. The precise theme and format should be decided by the W.G. and the meeting convened by the Chairman. Final decisions were to be made by the Bureau meeting in New Orleans, Oct. 15-17, 1982.

Possible themes and formats were discussed. Dr. Groves felt that open-ended symposia depending upon contributed papers were not always the most effective, and in any case were already provided for in existing sessions on Precambrian Geology at the Congress. He advocated that the W.G. promote a session in which invited speakers in various disciplines could explain how they thought research in their fields might contribute to understanding of the Archean.

Prof. Moorbath expressed reservations as to the desirability of the W.G. sponsoring a symposium dominated by invited experts. It was pointed out that several symposia at the I.G.C. in Paris had taken that form.

Prof. Eriksson felt that the theme and format of the "Early Crustal Genesis" special session at the A.G.U. annual meeting in June, 1982, might be an appropriate model.

Participants at the meeting each agreed to provide a listing of eight topics for inclusion at a symposium on Early Crustal Genesis - for discussion at a follow-up meeting the following night when a final decision would be made.

Next Meeting

Prof. Shen Qihan reported that a symposium on Precambrian Tectonics and Archean geochemistry was to be organized in China in 1983 by the Chinese Geological Society and the National All-China Committee on I.G.C.P. The meeting will take place in Beijing or its vicinity (provisionally, in September or October) and planned to last for 2-3 weeks. If W.G.4 wished to participate in the meeting, he requested that formal information be sent to the national All-China Committee in I.G.C.P. as soon as possible.

It was proposed (Viljoen) seconded (Baer) and unanimously approved that the next official meeting of WG4 be held in association with the projected Precambrian Tectonics and Archean geochemistry conference to be held in China in September or October 1983 (preferably September).

Further information pertaining to I.G.C. support of this conference was to be presented at the joint meeting of W.G.3 & 4, scheduled for the following night.

Opportunities for International Collaboration in Research

Hargraves supported the opinion of Eriksson that such collaboration was most likely to arise spontaneously as a result of contacts made during International Symposia such as the current ISAP meeting in Brazil.

Schorscher felt that in addition the distribution of information on current research activities in various countries might promot such collaboration.

Groves, supported by Naqvi, advocated that the W.G. adopt a more aggressive role in the promotion of such collaboration.

Lacking significant funds, the effectiveness of the W.G. in promoting collaboration more effectively was questioned. Beyond the spontaneous association referred to above, it seemed to be agreed that the careful, and detailed description of the short list of interdisciplinary "projects" to be adopted as the goals of the W.G. (Itam 1 on Agenda) and active promotion, of these by the Group, and especially its Chairman, was most likely to be fruitful in this regard.

Informal reports by attendees on Ongoing Research

Several members present felt that such off-the-cuff reports were inappropriate, and that the more detailed lists requested in the earlier motion would be more useful.

There being little enthusiasm for such reports, the item was abandoned, and the meeting adjourned at 10:20 p.m.

EOS, Vol. 63, No. 12, Pages 206–207, March 23, 1982

Early Crustal Genesis: A Report of the Airlie House Meeting

Over 100 scientists from seven countries met at Airlie House, Warrenton, Virginia, November 13–17, 1981, to discuss relevant scientific issues concerning the early evolution of the crusts of the terrestrial planets. The impetus for this meeting was twofold: to bring the planetary and Archean scientific communities together and to lay the framework for a long-term multidisciplinary research project.

The motivation for such a project stems from the fact that during the past several decades vast quantities of new data relevant to the origin and evolution of the planets have been acquired. As a result, a revolution has occurred in our approach to the evolution of crust-mantle systems of planetary bodies, with the appreciation that all but the smallest bodies in the solar system probably underwent a period of extensive melting and differentiation during their first few hundred million years of existence.

Through combined geological, geochemical, petrological, and geophysical studies of data from the moon, there have been significant advances made in development of models for the moon's thermal history, crustal formation, mantle evolution, volcanic activity, tectonic sequences, early meteoritic bombardment effects, and many other processes. The models, to be understood in the broader planetary context, must be further tested, modified, and verified by applying them to planetary bodies of different size, composition, and location. Although various types of imagery, spectral, and potential field data exist for Mercury, Venus, Mars and the Jovian and Saturnian satellites, the extensive geological, geochemical, petrological, and geophysical data necessary for detailed studies of models of crust-mantle evolution are not available. However, we have enough data to ask, and possibly to answer, some significant questions. Venus may provide key information in this regard.

For at least the next decade, the earth will be the only planetary body for which extensive new data sets can be obtained to rigorously test models of planetary evolution. Knowledge gained from the earth will advance our understanding of planetary evolution and can be used (1) to narrow the range of planetary models that must be tested, (2) to determine the critical data sets that will test the validity of the models, and (3) to define better the priorities of exploration of planetary bodies. Only a limited understanding of early earth history exists, especially of the formation and early evolution of its crust, a major planetary-scale problem. Inasmuch as the most critical data for planetary models are incorporated in the oldest parts of the Precambrian shields of the earth's continents, their study is extremely important to the general application of planetary models for crust-mantle evolution.

Cover. Precambrian sheeted dike complex, about 700–800 m.y. old, at Wadi Ghadir in the Eastern Desert of Egypt. These rocks may be taken as evidence for seafloor spreading during the late Precambrian. Previous inferences of Precambrian ophiolites are based largely on pillow lavas and layered gabbros. Pictured in the photograph, which was taken by A. Kröner, are M. F. El-Ramly, director of the Geological Survey of Egypt, and A. Rashwan, senior geologist with the Survey. The search for constraints on ancient tectonic styles is but one of the goals of the proposed new multidisciplinary research project on early crustal genesis described in the report on the meeting at Airlie House .

With these concepts in mind, an ad hoc steering committee met in January, March, and May of 1981 to formulate the goals and organizational structure for a research project in early crustal genesis. Out of their discussions came the concept for eight major scientific themes: (1) planetary formation, (2) physical and chemical evolution, (3) planetary volatiles, (4) tectonics, (5) crustal features and their development, (6) metallogenesis, (7) surface processes, and (8) paleobiology. The steering committee organized working groups around each theme, and the simultaneous gathering of these groups formed the basis for the Airlie House meeting.

For the first 3 days of the meeting the working groups met individually, and each summarized their deliberations with a set of scientific questions designed to lay the groundwork for future research. A synopsis of these questions is as follows:

1. *Planetary Formation.* Were there instabilities in the nebula gas, as well as the solids? Was the nebula gas sufficient to provide massive atmospheres for the terrestrial planets during their growth? How did the terrestrial planets acquire their more volatile constituents? What processes affected the inert gas contents of the terrestrial planets? What are the variations in fragment size and energy distribution of impacts with gravity, mass, velocity of projectile, and compositions of projectile and target? What was the nature of the first differentiations among silicates in the earth and Venus? What processes could have led to the loss of possible primordial atmospheres?

2. *Physical and Chemical Evolution.* Does the thermal environment during and immediately following accretion serve mainly to differentiate the silicate portion of the planet or to homogenize it? What is the relative importance of the various energy sources for driving planetary evolution? How can seismically derived structure be related to the chemical, convective, and mineralogic structure of a planet and its evolution? What role do volatiles play in affecting the behavior of planetary mantles? What are the implications of the lack of preserved terrestrial crust 4.5–3.8 AE old? How can thermal models be related to the geologic record? How does continental crust form and become stabilized? What is the evidence for and implications of the episodic nature of continental crust formation? What are the relationships of geochemical mantle reservoirs to the volume and age of the continental crust? Does the earth-moon 'fission' hypothesis substantially affect the interpretation of geochemical data on the earth's mantle-crust evolutionary history?

3. *Planetary Volatiles.* What are the initial and present volatile inventories and distributions in the earth and other planets? What is the time history of volatile transfer among various reservoirs? What are the mechanisms of transfer of volatiles and their relations to thermal and chemical evolution and tectonics? What are present states and histories of atmospheres and oceans of the terrestrial planets and their relation to surficial geology and biology?

4. *Tectonics.* What are the mechanics of subduction? What are the mechanisms of heat transfer through the lithosphere? What is the chronology of tectonic evolution? What significance can be attached to the distinctive compositions and relative abundances of the igneous, sedimentary, and metamorphic rocks of Archean terranes? How did crustal structure develop during the Archean and on what horizontal and vertical scales? Why is there hemispherical crustal symmetry on the moon, the earth, and Mars? Is there silicic crust on other planets? What is the tectonic style of Venus and does it have any analogies with present or past earth tectonics?

5. *Crustal Features and Their Development.* What are the relationships among earliest rocks, protocontinental crust, and growth of continents? What is the relative importance of primary versus secondary crusts on each of the terrestrial planets? What evidence might be found for terrestrial impact basins by taking into account a possible 'terminal' cataclysm of impacting objects? Is the Archean really different from the Proterozoic, and are these different from recent times? If so, then how? How do the characteristics of supracrustal units change with time?

6. *Metallogenesis.* What was the pressure-temperature regime in the Archean upper mantle? What is the nature of the mantle beneath Archean 'continental' crust? Where do kimberlites come from—lithospheric or asthenospheric mantle? What do they tell us about subcontinental, especially Archean, mantle? Do metal anomalies in ancient crust control the formation of ore deposits in younger rocks? How has the concentration and oxidation state of sulfur in ancient oceans changed with time?

7. *Surface Processes.* What was the character of the earliest crust and surface on the earth and when was it formed? Is the record of tectonic, volcanic, and surface processes observed or inferred from planets applicable to the earth? Is the record of impact and the effects of the formation of multiring basins on crustal evolution (as recorded on the lunar crust before approximately 4 AE) applicable to other planets? What do the secular changes within the sedimentary record of old (3.5–3.0 AE) belts imply for changes in the tectonic-thermal regime? What do the observed differences between older (3.5–3.0 AE) and younger (2.9–2.5 AE) greenstone belts imply about the tectonic and surface evolution of the Archean earth? What can weathering profiles or chemical and isotopic compositions of Archean sediments tell us about the evolution of the Archean atmosphere and hydrosphere? What does the sedimentary record tell us about climate and its variation with time? Can a bridge be built between impact-dominated regolith development (moon, Mercury) and endogenically dominated weathering and diagenetic processes (Mars, earth)?

8. *Paleobiology.* How soon after accretion and core formation did the earth cool to a temperature low enough to permit the existence of liquid water and the survival of prebiotic organic matter? When did the earth's atmosphere form, and what controlled its earliest composition and evolution? What can be inferred about the geochemistry of seawater in pre-Archean and Archean times from the geochemistry of ancient sedimentary formations? What are the relationships between the records of geochemical changes in Archean sediments and the development of biological activity? What geologic factors controlled the nature of sedimentary environments, and how did these change over time? What factors determined the pressure of oxygen in the atmosphere and hydrosphere, and how did these factors vary over time? What factors controlled the cycling of carbon on the primitive earth, and how did these vary over time?

The above sets of questions reflect only the briefest summaries of the detailed questions set out by the working groups. As can be seen, there is overlap among the various groups. This was to be expected because of the somewhat arbitrary boundaries dividing the subject matter. To stimulate interaction among the various groups, the fourth day of the Airlie House meeting involved multidisciplinary discussions clustered about only four themes: (a) crustal history, >3.8 AE; (b) crustal history, 2.5 to 3.8 AE: (c) tectonics; and (d) atmospheres, oceans, and life. Each of these four groups outlined topics for future research which would have some chance of significant accomplishment during a 5- to 10-year project. These are summarized as follows:

Crustal History, >3.8 AE. (1) Theoretical modeling of a planet's thermal, mechanical, and chemical evolution during accretion and in the following 0.5 AE; (2) Intensive multidisciplinary work on the oldest known terrestrial rocks; (3) Observations of the Venusian crust as a possible early earth analog; (4) Specifications of the conditions and petrological processes necessary to allow formation of continental-type crust.

Crustal History, 2.5–3.8 AE. (1) Identification and understanding of those aspects of the Archean geological record that might provide constraints on both the thermal and chemical evolution of the early earth; (2) Recognition and interpretation of secular trends in crustal volumes and compositions from the early Archean to the early Proterozoic.

Tectonics. (1) Field and theoretical studies leading to evidence (or lack thereof) for plate tectonics in the Archean; (2) Clarification of the necessary and sufficient conditions for lithosphere subduction and application of these constraints to terrestrial Archean and Venusian tectonics; (3) Development of testable alternative models to Phanerozoic-style plate tectonics.

Atmospheres, Oceans, and Life. (1) More complete exploration of the record of sedimentary abundances, coupled with measurements of isotopic ratios of all volatile elements; (2) More complete consideration of nonreducing atmospheres as prebiotic reaction systems; (3) Detailed studies linking the chemistry and sedimentology of specific environments such as stromatolites and banded iron formations.

The meeting ended with reports from representatives of potential U.S. funding agencies, including the National Science Foundation (NSF) and the National Aeronautics and Space Administration (NASA); NSF especially encourages proposals from multidisciplinary consortia in all areas of the earth sciences, including projects related to early crustal genesis; NASA will continue support of workshops, including field and topical conferences, but budgetary cutbacks prevent major new funding of early crustal genesis research until at least 1984. It is recognized, however, that in the meantime an early crustal genesis project could help sustain the planetary science community, aid in the defense of existing programs, help intelligently plan for planetary exploration by raising key scientific issues, and enable some good science to be done.

For more information, a position paper on the proposed project is available from the Lunar and Planetary Institute, 3303 NASA Road One, Houston, Texas 77058. (*LPI Technical Report 81-08;* postage and handling, U.S. and foreign surface mail, $3.00; foreign air mail, $5.00).

This meeting report was written by Lewis D. Ashwal and Roger J. Phillips of the Lunar and Planetary Institute, NASA, Houston, Texas.

Memo to: ILC W.G. 4 (Archean) members
From: R.B. Hargraves

This is a brief summary of the proceedings of the Early Crustal Genesis Workshop organized by the Lunar and Planetary Institute in November, 1981. Distribution of this to W.G. 4 (Archean) members was promised at the meeting in Salvador - as per previously distributed minutes. Will all W.G. members please provide to Hargraves a listing of what they perceive as major Archean problems that can be translated into practical, multidisciplinary international research projects - by the end of October 1982.

APPENDIX 7

The second part of the meeting is held together with WG 4 on 10 September 1982 in the Itapoan Room of the Othon Palace Hotel, Salvador, Bahia and begins at 20.10 hours. Participants are as listed above as well as those of WG 4. Chairman Price attends the entire session.

Chairman Price opens the meeting by summarizing again the financial situation of the ICL and by giving a short review of the history of the Lithosphere Project.

WG 4 Vice-Chairman Hargraves summarizes the main points discussed at the meeting of WG 4 on 9 September, Kröner follows by summarizing the discussions of WG 3.

Kröner gives a short review of activities in connection with a scientific meeting in China in cooperation with IGCP Project 92 and the IUGS Commission on Tectonics. Dr. Shen Qihan (guest from Peking, China) then reads from a letter stating that the Chinese authorities would be happy to host a meeting on Precambrian tectonics and Archaean geochemistry, to be held in Peking in September 1983. After some discussion both WG's recommend to accept the invitation and decide to hold official business meetings at this occasion. Kröner is requested to find out what arrangements will be made, financially and organizationally, to hold this meeting. It is anticipated that about 40 non-Chinese scientists may participate. A lengthy discussion follows on the definition of an appropriate title for an ICL-sponsored symposium at the meeting, and agreement is finally reached on the provisional title" Structure and evolution of tectonic boundaries in the Precambrian Lithosphere". There is an unanimous request that field trips in China should include tectonic boundaries, if possible. Hargraves and Kröner will report on the China trip to the ICL Bureau.

Kröner reports on the official WG 3 symposium at the IGC in Moscow in 1984 (see point 8 above) and invites WG 4 to participate. After some discussion on the proposal for a trip to the site of the deep hole in Karelia it is unanimously agreed that both WG's should request the ICL Bureau to approach the Congress Organizers in Moscow in this matter.

The meeting ends at 21.45 hours.

Mainz, 17-9-1982

A. Kröner

Joint Meeting of WG 3 & 4
Thursday, 9th September, 1982, 8:00 p.m.

R. Price (Chairman) and others (no detailed listing of participants was made)

Price explained that the Commission's intention was that WG's should consist of 12 official members, plus a cadre of corresponding members, interested in the Project from among whom future members of the W.G.'s might be selected.

Financial support for participation in official W.G.-sponsored meetings was nominally restricted to official W.G. members only, but ultimately, the limited resources available could be distributed at the discretion of the W.G. Chairman.

Proceedings of the previous night's W.G. meetings were briefly summarized by Hargraves and Kroner.

Kroner is travelling to China in the near future, for discussions with the Chinese authorities concerning the proposed International Conference plus field-trips next year. Price suggested that WG's 3 and 4 should formally accept the invitation of the Chinese Committee to participate in this conference which would be supported by the Commission and request permission to stage a one-day workshop during the conference devoted to one particular theme. The subject for the workshop was discussed at length, without a final decision, but revolved around the theme of the nature and tectonic significance of Boundaries in the Precambrian.

More specific information will be available, it is hoped, after the I.G.C. meeting in New Orleans on October 15-17, 1982.

R. A. Hargraves

APPENDIX 8

INTERNATIONAL CONFERENCE ON
PROTEROZOIC 83
PROVISIONAL REGISTRATION FORM

(Please Print and Use Block Letters)

1 Name.....(Surname last)

2 Address.....

Telegrams Telex

3 Nationality.....

4 I wish to register as attending/non-attending member

I shall be accompanied by:.....

5 Language

6 Accommodation requirements. Please tick Provisional choice.

The range of nightly charges for different hotels is provisional and does not include meals.

Details will be announced in the second circular

Hotel single (U S $ 35.00-50.00) double(U S $30.00-60.00)

Halls of residence (subject to availability) single

Private arrangement

7 Excursions. Please indicate provisional interest

Pre-conference: Victoria Falls Luangwa Valley

Post-conference: Copperbelt (tick one only)

8 I wish to submit paper Yes/No

a) Title

Place.....Signature.....

Please return the completed provisional registration form to the Organising Secretary by 31st August 1982.

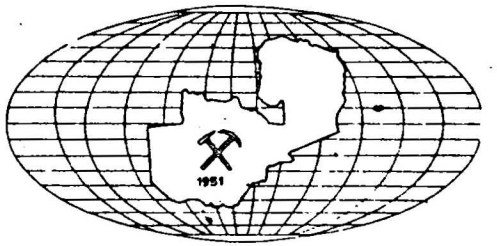
PROTEROZOIC 83

AN INTERNATIONAL CONFERENCE ON THE PROTEROZOIC

LUSAKA, ZAMBIA

11-13 APRIL 1983

FIRST CIRCULAR WITH PROVISIONAL REGISTRATION FORM



CORRESPONDENCE AND ENQUIRIES:

The Organizing Secretary
Proterozoic 83
Geological Society of
Zambia
P.O. Box ~~00450~~ 50135
Lusaka
ZAMBIA

PROTEROZOIC 83

The conference is being organised by the Geological Society of Zambia in collaboration with:-

Geological Survey Department of G R Z
Minex Department of Zimco Limited
University of Zambia
Zambia Consolidated Copper Mines Ltd
Geological Society of Africa
AGIP-SPA
Saarberg Interplan
P N C

This will be the first international conference of its kind to be held in Africa on the Proterozoic. The conference has been assured the support of UNESCO and IGCP.

AIM

The Proterozoic occupied a significant time interval in the evolution of the earth. It is the aim of PROTEROZOIC 83 to provide an international forum for a global review of Proterozoic.

The following topics are intended to be covered by the conference:

1 Palaeogeography and palaeoenvironments
2 Stratigraphy and correlation
3 Sedimentology and diagenesis
4 Magmatism, geochemistry and geochronology
5 Mineralisation
6 Orogenic and tectonic processes

WHY IN ZAMBIA

Most of the pre-Karroo basement in Zambia is of Proterozoic or earliest Palaeozoic age. A number of tectonothermal episodes can be recognised: e.g. the Eburnian, the Kibaran, and the Pan-African of the Lufilian and Mozambique belts. Of great importance to Zambia are the syngenetic, stratabound copper-cobalt deposits of Katangan age in the Zambian Copperbelt. Zambia contains many features of Proterozoic geology which would form the basis of discussion in PROTEROZOIC 83.

DATES

Conference sessions will be held on 11,12 and 13 April 1983. There will be pre-symposium excursions of tourist interest, and a post-symposium geological excursion (see below).

VENUE

The conference will be held at the University of Zambia or at Mulungushi Hall in Lusaka. Accommodation will be in hotels and in halls of residence.

LANGUAGE

The language of the conference will be English and French.

PAPERS

Abstracts (maximum 300 words) should be submitted before 1 October, 1982. A booklet of abstracts accepted for the conference will be sent to all registrants. The full text of all accepted papers should be prepared before the conference, and authors will be asked to bring reprints for distribution at the conference. The papers will be published in a proceedings volume.

REGISTRATION

All those attending the conference will be required to register. The registration fee is 200 U S dollars, payable in a negotiable currency.

TRAVEL

All intending visitors should check with their nearest Zambian Embassy, Consular Representative or Zambia Airways Office to ascertain the current requirements for Passports, Visas, Health Certificates and Currency. The Zambia National Tourist Board will help with travel arrangements to places of tourist interest in Zambia.

EXCURSIONS

Pre-conference excursions of tourist interest will be organised to the Victoria Falls and the South Luangwa National Park over the weekend 8-10 April. Details will be announced later. Please indicate your provisional interest in one of these two excursion on the attached registration form.

A post-conference excursion to the Copperbelt will be organised. This will run for 4 days and 3 nights, 14-17 April. Travel will be by coach. The approximate cost will be 300 U S Dollars. Details will be given in the next circular. Please indicate your provisional interest in this excursion on the attached registration form.

FILMS AND EXHIBITIONS

A selection of recent films on earth science topics, with particular reference to the Zambian Copperbelt, will be shown at the conference. Scientific displays of equipment and models of geological interest will also be on view.

OTHER INFORMATION

Information regarding social events, and more details on all the above subjects given in the second circular.

ENQUIRIES

All enquiries should be addressed to:-

The Organizing Secretary
PROTEROZOIC 83
Geological Society of Zambia
P O Box ~~63773~~ 50135
Lusaka
ZAMBIA