COMMONWEALTH OF AUSTRALIA

DEPARTMENT OF NATIONAL DEVELOPMENT

BUREAU OF MINERAL RESOURCES, GEOLOGY AND GEOPHYSICS

RECORD No. 1963/9

REPORT ON A VISIT TO EUROPE AND NORTH AFRICA, 1962

by

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SUMMARY

The writer visited Europe and North Africa during February to August 1962. The chief objectives of the trip were to study seismic noise and large-scale seismic refraction work.

Seismic noise was studied with the Institut Francais du Petrole and the refraction work with the Compagnie Generale de Geophysique. A good deal of time was spent with field parties in France, Algeria, Tunisia, and Sicily.

Brief visits were also made to other organisations in France, Algeria, Tunisia, Italy, Holland, Germany, and Britain.

List of Organisations visited, with abbreviations used

Agip	- Agip Mineraria, Milan
Shell	- Bataafse Internationale Petroleum (Shell), The Hague
BP	- The British Petroleum Company Limited, London
Bundesanstalt	- Bundesanstalt fur Bodenforschung, Hanover
CFP(A)	- Compagnie Francaise des Petroles (Algerie) Paris and Hassi Messaoud
CGG	- Compagnie Generale de Geophysique, Paris and Algeria
GSI	- Geophysical Service International Limited, London
-	- Geografrance, Tunisia
Hall-Sears	- Hall-Sears Europa, NV, The Hague
IFP	- Institut Francais du Petrole, Paris
Prakla	- Prakla Gesellschaft fur praktische Lagerstaettenforschung GmbH, Hanover
Seismos	- Seismos GmbH, Hanover.
SSL	- Seismograph Service Limited, London
-	- Societe de Prospection Electrique (Schlumberger), Paris

1. INTRODUCTION

Following Cabinet Approval No. 101 of 21st April 1959 authorising the expenditure of an additional £1,000,000 per annum by the Commonwealth Government on the search for oil, provision was made for officers of the Bureau of Mineral Resources, Geology and Geophysics, to be sent overseas to become familiar with oil exploration methods and techniques currently in use. In 1960 Mr A. Turpie of the Bureau made a brief visit to the USA to study specific seismic equipment purchased by the Bureau and in 1961 Mr E.R. Smith visited the USA for six months to study new field and laboratory techniques employed in seismic reflection work and also playback-centre methods used to obtain maximum information from magnetic recordings of seismic data.

Through the Bureau's contacts with the IFP and the CGG it was possible to arrange for the author, another Bureau officer with seismic experience, a training programme at research centres in France and also with field crews operating in France and North Africa. These French organisations have had considerable experience and success in the rapid exploration of relatively unknown sedimentary basins and have developed techniques which it was thought might be of practical value in some areas of Australia. The specific purposes of the author's visit were to study the following aspects of seismic prospecting:

(a) seismic noise, detection and analysis of its components, the mode of generation and methods for suppression,

(b) large-scale seismic refraction reconnaissance procedures, party equipment and organisation, and analysis of results.

The author left Australia for France on 20th February 1962 and returned to Australia on 18th August 1962. During this time he visited nine seismic crews in Europe and North Africa and spent a considerable time with the IFP and CGG research and data-processing centres in Paris. Brief visits of one week or less were made to eleven other major organisations concerned with seismic exploration in the European area.

2. ITINERARY

Dates (1962)	Movements	Organisations visited
20th & 21st February	Melbourne to Paris, by air	
22nd to 28th February	Paris	IFP
1st March	Paris to Puyoo, south-west France	

Date 1962	Movements	Organisations visited
2nd to 16th March	Bidache, south-west France	IFP experimental crew
16th March	Bidache to Paris	
17th March to 5th April	Paris	IFP and CFP (A)
5th April	Paris to Hassi Messaoud, Algerian Sahara, by air	
6th April	Hassi Messaoud to CGG refraction party 2079 near Guerrara, by road	
7th to 23rd April	Near Guerrara, Algerian Sahara	CGG refraction party 2079
24th April	Guerrara to Hassi Messaoud, by road	
25th April	Hassi Messaoud	CFP (A)
26th & 27th April	Hassi Messaoud to CGG refraction party 2090 near In Amenas, by road	
28th April to 8th May	Near In Amenas, Algerian Sahara	CGG reflection party 2090
9th May	In Amenas to Algiers, by air	CFP (A)
10th May	Algiers to Ghardaia, Algerian Sahara, by air	
11th May	Ghardaia to Hassi Menkel, by road	
11th to 15th May	Hassi Menkel, Algerian Sahara	CGG reflection party 2114
16th May	Hassi Menkel to Ouargla (Sahara), by road	
17th & 18th May	Ouargla	CGG
19th May	Ouargla to Paris, by air	
20th May to 2nd June	Paris	IFP
3rd June	Paris to Tunis, by air	
4th June	Tunis to Gafsa, Tunisia, by road	
4th to 6th June	Near Gafsa	Geografrance weight-dropping party

Date 1962	Movements	Organisations visited
6th June	Gafsa to Tunis	
7th June	Tunis to Trapani, Sicily, by air and road	
8th to 11th June	Near Trapani	CGG marine seismic crew
12th June	Trapani to Milan, Italy, by road and air	
12th to 16th June	Milan	Agip Mineraria
17th June	Milan to Paris, by air	
18th June to 3rd July	Paris	Societe de Prospection Electrique, IFP, and CGG
3rd and 4th July	Paris to Romans, south-west France, by train	
4th to 6th July	Romans	CGG reflection party 1319
7th to 24th July	Paris	IFP and CGG
25th July	Paris to The Hague, Holland, by air and road	Bataafse Internationale Petroleum (Shell)
25th to 27th July	The Hague	Shell and Hall-Sears
27th July	The Hague to Hanover, Germany, by air	
28th July to 1st August	Hanover	Seismos, Prakla, and Bundesanstalt.
1st August	Hanover to London, by air	
2nd to 15th August	London	BP, SSL and GSI
16th to 18th August	London to Melbourne, by air	

3. GENERAL DESCRIPTION OF STUDY PROGRAMME

22nd to 28th February - IFP, Paris

During this period I was introduced to the IFP organisation at Rueil-Malmaison near Paris. I commenced the study of seismic noise by the reading of a number of classical articles and textbooks that were recommended by the IFP. Following this I began the study of an IFP report on an experimental survey in the Guern Bou Kramsa region of the Sahara, during which extensive noise tests were made.

FIGURE 1

FIGURE 2

Figures 1 and 2. Water tanker belonging to drilling contractor 'Forex' employed by IFP experimental party. The truck is a GMC 6x6. Tank capacity is about 600 gallons. Note the 'tailoring' of the tank to the truck chassis and the distribution of the water load.

1st to 16th March - IFP Experimental Seismic Party, Bidache

At the time of my visit the IFP experimental crew was working in a hilly region bordering the Pyrenees in south-western France. A contractor had previously done seismic work in this area to detail a possible oil structure, but results had been very bad on certain critical reflection profiles. The IFP had been called in to determine whether it was possible to obtain better results on these profiles.

The composition and equipment of the IFP crew were quite conventional. There were two geophysicists permanently with the party. and the party's supervisor spent about 40 per cent of his time with the party in the field. The seismic amplifiers used were HTL 7000B. A TI Magnedisc was used for magnetic recording. The party was equipped with 1800 geophones; half of them were of standard reflection type (Electro-Tech EVS) and the other half were Hall-Sears miniatures. The 7000B amplifiers were considered to be quite satisfactory for experimental work although the set in use by the IFP had two modifications. The first of these was the provision of a set of low-frequency pre-filters before the input transformers to prevent overloading of the input transformer primaries with low-frequency energy. This overloading apparently occurs readily when large numbers of geophones are used. Variable resistors were also incorporated in the pre-filter units to allow balancing of cable resistances to various geophone groups when long spreads were used, thus ensuring greater trace similarity. The second modification provided for variable gain in addition to AGC. On the IFP set it was possible to adjust separately the initial gain, the time constant for increase in gain, and the final gain; the variable gain was tripped by the time break.

The IFP experimental survey near Bidache commenced with two noise tests and then tests of various shooting parameters in separate localities, thus following standard IFP procedures. As these procedures will be described in detail in a later note to be prepared for the Bureau's seismic group they will not be described here. These tests indicated an optimum shot-hole pattern and shot depth and a suitable geophone arrangement, the geophone spacing being determined by the noise velocities measured. The shot-to-geophone arrangement decided upon was interesting. For a first shot the nearest geophone group to the shot was centred 130 metres from the shot-point and the farthest at 590 metres, all 24 geophone pegs being on the same side of the shot-point. The geophones were then moved away from the shot-point so that the nearest group was at 610 metres and the most distant at 1070 metres and a second shot was fired at the same shot-point. Thus there was effectively a spread of 48 traces on one side of the shot-point. This spread was shot from the other end in the same manner. The IFP do not like split spreads and rarely use them because (a) ground roll and other surface noise is much greater close to the shot, and (b) if the correct geophone spacing is used near the shot-point the traces for these geophones are likely to be disturbed by shot-hole debris and mud falling nearby. Noise tests will usually show how important it is to displace the shot-point from the geophone spread.

Playing back of magnetic recordings was not done in the field but in the Paris playback centre. Uncorrected variable-area records were then sent back to the field crew where they were assembled to form an uncorrected variable-area cross-section. Static corrections were nearly always derived from reflections rather than from first breaks.

Corrected record cross-sections were made much later after detailed study of corrections. Results obtained by the IFP experimental crew visited in the Bidache area were appreciably better than those previously obtained by a contractor because:

(a) deeper shot-holes were used, in three-hole patterns instead of single holes,

(b) three times as many geophones were used, with a more scientifically determined spacing between geophones,

(c) geophone spreads were displaced from the shot-point to avoid excessive surface noise.

17th March to 5th April - IFP and CFP (A), Paris

The greater part of this period was spent studying a very interesting IFP report which effectively summarises the findings of the IFP after three years of study and field experimentation on the reflection method. The theme of this report is that it is possible to follow a logical testing procedure to determine the best recording parameters instead of following the old method of doing a series of empirical tests varying one parameter at a time. As this report will be referred to in a separate note to the seismic group of the Bureau it will not be described here but it may be said that it represents a valuable contribution to seismic reflection work. I also studied a number of other IFP reports that dealt with specific experimental surveys made by the IFP, including interpretations of noise tests, studies on the influence of different altitudes of geophones in the one group, and the influence of errors in the spacing and weighting of geophones.

During this period I also made a brief visit to the offices of the CFP(A) and inspected that company's central playback centre where a set of Carter MT4 playback equipment was used.

7th to 23rd April - CGG Refraction Party 2079, Guerrara, Algeria

The CGG refraction party visited in the Sahara was engaged on a detailed refraction survey in an area where reflection work had completely failed to produce useful structural information. This visit was of particular interest to me because the party was using the classical refraction method as developed by the French in the Sahara over a number of years, while at the same time trying out a new method for the first time.

The personnel of the party consisted of 30 Europeans (7 of whom were guards for the explosives) and 55 indigenous workers. The more important personnel comprised:

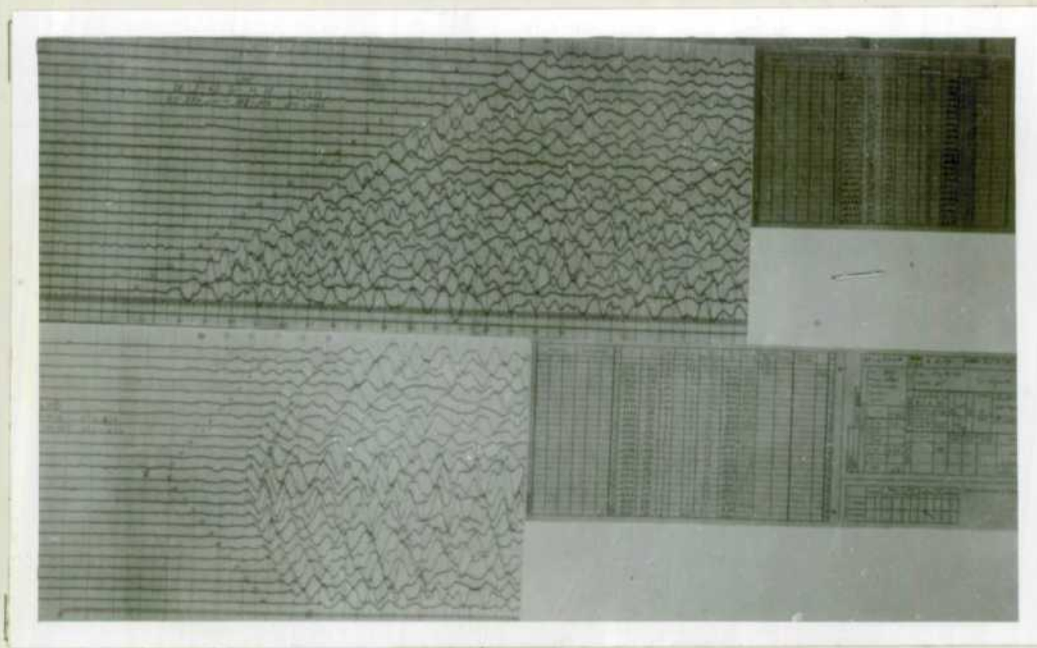

Figure 3. Refraction record obtained using Gardiner method (top) and refraction record from same area using right angle offset method (bottom).

Figure 4 Preparing a surface pattern shot for refraction shooting.

Figure 5 First unit in a row of charges. Note detonator wire on left hand side and fuse-cord on the other side

1 party leader

2 computers (geophysicists)

2 junior computers

2 observers

1 junior observer

3 shooters

4 surveyors

1 surveyor-computer

1 administrative secretary

1 camp manager

1 mechanic

The seismic equipment consisted of refraction amplifiers type 59, designed and manufactured by CGG, used in conjunction with an SIE PRO-11-12 camera and a Carter FR1 magnetic recorder. The party was equipped with 600 Hall-Sears 4-c/s geophones and a number of heavy geophone cables 4200 metres in length.

Spacing between geophone groups was 350 metres, and a spread of 24 traces covered 8400 metres or roughly five miles. Shots were fired at every third geophone peg on the profile. The spacing between successive shots and the shot-to-geophone distances used depend on the refractors being mapped and the aims of the survey, but it is general CGG practice to have a considerable amount of geophone spread overlap between adjacent shots. This is commonly as much as 50 percent, its purpose being to avoid the necessity to use doubtful traces in the mapping of a refractor. For the shots fired on the profile the refraction method used was essentially the Gardiner method.

As the profile progressed using the Gardiner method, shots offset a considerable distance at right angles to the geophone spreads were also fired from both sides of the profile. These shots were located a little more than the double offset distance* from the profile to take advantage of the large increase in energy which occurs at this distance (Clement & Layat, 1961), so that relatively small charges could be used (e.g. 100 kg of N19 fired on the surface at a distance of 6300 metres). An example of a seismic record obtained in this way is shown on Figure 3 together with a Gardiner-type record from the same area. In practice the distance between adjacent profiles was made such that the offset shots for a particular profile were located on the two profiles on either side of the profile. As in the case of the conventional shots there was considerable overlapping of geophone spreads for successive offset shots.

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* i.e. twice the horizontal distance between the shot-point and the point ('critical point') on the refractor where refracted energy strikes the refractor at the critical angle, $i_C = \sin^{-1} \frac{V_1}{V_2}$

Figure 6 Shooting truck on CGG refraction party, showing VHF radio aerial. This type of radio communication has proved very effective in the Sahara.

Figure 7 Cable truck on CGG refraction party, showing heavy geophone cable on power driven reel.

The method of using shots displaced at right angles to the profile has an advantage over the original 'Clement method', in which shots were located on the profile a little more than twice the offset distance from the geophones. This advantage is that all the geophones are located close to the double offset distance despite the fact that large distances between geophones are used. In the original method it was necessary to use fairly close geophone spacings in order that all geophones should be close to the 'critical point'. The method using shots offset at right angles has the disadvantages that it is very inaccurate as far as determination of refractor velocities is concerned and that all refraction paths for a given shot lie in different planes. If the method is used in an area where velocities are very well known, or if it is used in conjunction with suitable conventional shots, the first disadvantage is not serious; and if offset shots are fired in both directions between two adjacent profiles, uncertainties arising from the refraction paths being in different planes are greatly reduced. On the survey visited, useful structural information was being obtained from a refractor that could not be exploited by the Gardiner method. However, it must be admitted that faults are often very difficult to detect by means of the right-angle offset method.

On the party visited, surface charges were used for all refraction shots. The explosive used was 'N19' in powdered form contained in cardboard cartons. The surface charges were always arranged in a standard pattern. This pattern consisted of a variable number of rows of charges, each row being aligned in the direction of the profile and containing four separate charges 20 metres apart (Figure 4). The unit charge was usually one carton (10kg). The distance between rows of four charges was 25 metres, and sufficient rows were used to make up the total charge required. A detonator was placed close to the charge in each row farthest from the geophones and connection made from each detonator to each of the four charges in its row successively by means of a detonating fuse-cord (Figure 5) which passed through a slit in each explosive carton. The detonators were wired in series to the firing line. On firing, the four charges in each row explode successively as detonation proceeds from the detonator along the fuse-cord at approximately the velocity of seismic waves in the refractor being studied.

The 4- c/s refraction geophones used for recording were used in groups of 24 per trace. These were arranged in four rows perpendicular to the profile, with 10 metres between rows and 10 metres between geophones within a row. CGG considers that 10 metres is the separation required to ensure complete decoupling and hence best cancellation of random noise. Geophones were always buried with a cover of at least 10 cm.

For refraction recording, no low-cut filtering is used. The high-cut filters had a cut-off at 40 c/s. For all but very close refraction shots CGG uses the same gain on all traces. This is considered very important as it enables energy changes from one trace to another to be recognised easily. Such changes may indicate a change from one refractor to another, or the presence of a fault, or some other feature. If it is necessary to use lower gains on traces very close to the shot it is recommended that the gains be varied in groups of traces i.e. the first six traces may have the same gain, the next six an equal but higher gain etc. No AGC is used, as, apart from amplitude considerations, AGC often introducesphase differences.

(Facing page 8)

Figure 8 Wagon Jack percussion drill mounted on the side of a Failing 1500 rig truck

Figure 9 CGG personnel tent and fly are supported by a collapsible frame of galvanised tubing. Both ends of the tent have canvas walls zippered in the centre as above. These walls can be rolled up to reveal inner mosquito netting walls which also have a zippered opening in the centre. The rubberised - canvas floor mat is firmly fastened to the tent wall all round, thus giving good protection from blowing sand and dust.

During my visit to the CGG refraction party I was able to study CGG interpretation methods and gain experience in the preparation of delay-time curves by carrying out for myself under the supervision of the party leader the complete interpretation and plotting of a refraction profile, beginning with the records themselves.

25th April - Hassi Messaoud, Algeria

On 25th April the CFP(A) arranged for me an inspection tour of the most important oilfield in the Sahara, at Hassi Messaoud. After the geology and history of development of the field had been explained to me I was able to see drilling operations, manufacture of drilling mud, the geological investigation of drill cores, the collection centre for oil produced, separation of waste gas, the oil pipeline pumping centre, and the bases of the two oil companies exploiting the field.

26th April to 8th May - CGG Reflection Party 2090, In Amenas, Algeria

CGG Reflection Party 2090, working in the central part of the Sahara, had a staff of 26 Europeans and 53 indigenous labourers. This includes the drilling team of 19 which was provided by another contractor, viz. 'Forex'. The recording crew used Carter reflection amplifiers and a Carter FR1 magnetic recorder. It was equipped with 900 EVSL geophones and five light geophone cables 720 metres in length. For drilling, the party was equipped with a Failing 1500 rig (air or water) and three Wagon Jack percussion drills, one of which was mounted on the same truck as the Failing 1500 (see Figure 8).

While visiting this party I concentrated most of my attention on the CGG method of deriving static corrections from reflections and on the special methods used by the 'Forex' team for drilling holes in sand and in hard limestone. Some of the camp equipment was also interesting, e.g. the evaporation-type air conditioners used (see Figures 10 and 11). On one occasion I was able to accompany some of the staff from this party on a reconnaissance trip by vehicle into a typical sand-dune area and was thus able to gain valuable experience of transport problems and possibilities in this type of terrain. For travel in sand-dune areas the party was equipped with a number of Dodge 6 x 6 Power Wagon trucks. These used second-hand aircraft tyres (DC.3 size) with reduced air pressure in sand. This arrangement proved highly effective and economical.

As it is intended to prepare a separate note on the CGG method of computing static corrections for reflection profiles, it will not be described here.

Recording technique used by this crew was conventional except that a large number of geophones and holes were used. Records obtained were poor to fair in quality. Thirty-two geophones per trace were employed in a standard group arrangement of four parallel rows of eight geophones with 10 metres between geophones and 10 metres between rows. This arrangement was not designed for any particular set of surface conditions since these varied greatly from solid rock to deep sand. All geophones were buried. Recordings were originally made with widest possible amplifier pass-band and tapes were played back immediately after the shot with a narrower pass-band.

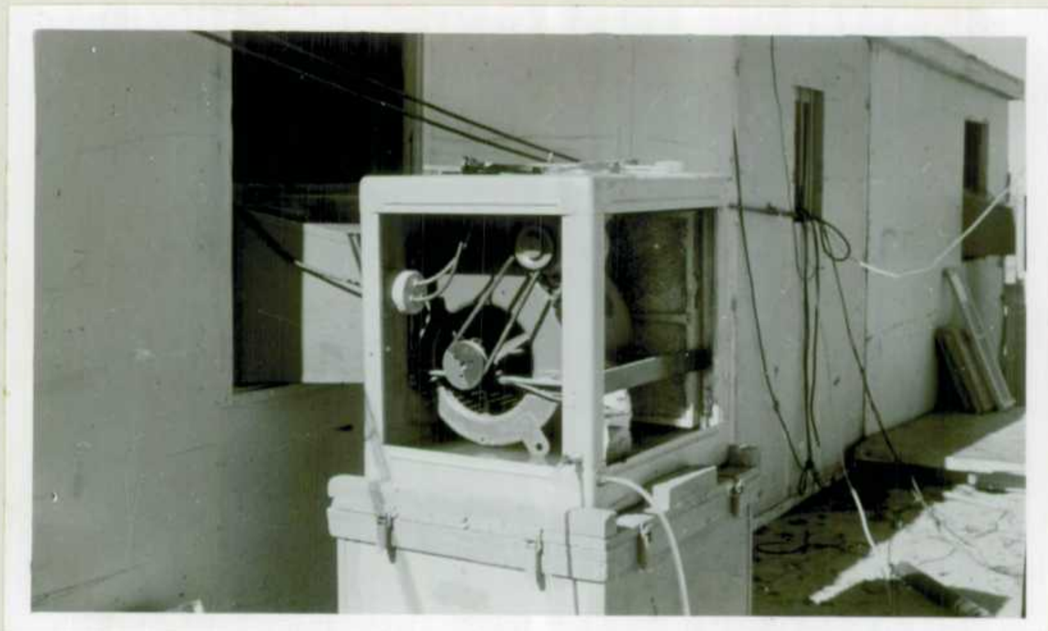

Figure 10 Evaporation – type air cooler used on CGG parties in the Sahara, shown while being fitted to a prefabricated office hut. These units cost about £(A)130 and are very effective in dry heat.

Figure 11 Evaporation - type air cooler and exhaust fan fitted to a large tent used as daytime sleeping quarters in the Central Sahara.

Shot-hole patterns used consisted of a variable number of holes drilled to three metres. The holes were arranged in rectangular grid patterns and the number of holes per pattern ranged from 33 to 90 depending mainly on how far the drilling crew was ahead of the recording crew. Spacing between holes was generally 10 metres. Holes were each loaded with 1 or $1\frac{1}{2}$ kg and tamping was done with sand.

Drilling in sand was accomplished very quickly using the 'clarinette and balise' method. The clarinette was simply a piece of 21/27-mm gas tubing (c.f.1 in. water pipe) with a right-angled bend at one end, which was attached by rubber hose to the air compressor of a drill truck. The balise consisted of a 3.4-metre length of $2\frac{1}{2}$-in. exhaust pipe or gas tubing with a handle attached at right angles at one end. To drill, the balise was placed vertically on the sand, the clarinette was inserted a little deeper than the bottom of the balise and the air pressure turned on to blow sand and compressed air up to the space between clarinette and balise. The balise was forced down manually by two workers each of whom pulled on one end of the horizontal handle near the top of the balise. Holes could be drilled in dry sand in this way in a matter of seconds. It is recommended that for rapid operation two balise teams should be used for one clarinette.

Loading was done while the balise was still in the hole after withdrawing the clarinette. A detonator and 3.5 metre lead were usually tied to a small stone and lowered to the bottom of the balise. Explosive powder was then poured in and the balise withdrawn, leaving charge, detonator and all but the top end of detonator lead immersed in sand.

Drilling of shallow holes in hard rock was accomplished by means of pneumatic hammer-type drills known as 'Wagon Jack'. This type of drill is relatively light and inexpensive apart from the provision of an air compressor that can maintain a pressure of at least 7 kg/cm^2 and deliver air at the rate of about 7 metre^3/min. One of the party's Wagon Jacks was mounted on the side of a Failing 1500 rig truck with air connexions from the rig compressor to both the Failing rig and the Wagon Jack. This was a particularly economical and convenient way of increasing the drilling capabilities of the Failing unit. It was possible to change from rotary drilling with water or air to percussion drilling with the Wagon Jack in a matter of minutes. Where hard layers of limestone were present at the surface, drilling of holes to a depth of three metres was several times as fast with the Wagon Jack as by rotary drilling.

11th May to 16th May - CGG Reflection Party 2114, Hassi Menkel, Algeria

Hassi Menkel is situated about 30 miles west of Hassi R'mel gas field. Party 2114 was similar as regards organisation, drilling, and recording equipment to the previous reflection party that I visited. However, the geological and geophysical problems in this area were quite different. The survey in progress provided a good example of the value of synthetic seismograms in interpretation of field seismic records. The records obtained in this area showed a number of reflections at fairly regular intervals; some of the reflections were believed to be 'multiples'. A considerable amount of field work was directed towards eliminating these 'multiples. Later, when a synthetic seismogram was available for this area, it was found that the regular repetition of reflections was in fact due to a regular occurrence in depth of velocity discontinuities. While visiting this party I was able to learn something of CGG field methods for determining velocities in the upper layers.

20th May to 2nd June - IFP, Paris

During this period I was able to study synthetic seismograms and seismic models at the IFP near Paris. The IFP has done a considerable amount of experimenting with the analogue bar method of producing synthetic seismograms but considers that the introduction of the IBM 7090 computer has made the production of synthetic seismograms cheaper by computer. In addition to experimenting with one-dimensional models (i.e. analogue bars) the IFP has done a considerable amount of research using two-dimensional seismic models and a small amount of work using a three-dimensional model. Some useful results were obtained with two-dimensional models in the study of refraction by thin layers. However, it is found that laboratory seismic models do not in general present good analogies to field conditions. One of the main reasons for this is that Poisson's ratio, as measured in the laboratory models, is usually about 0.25 as predicted by theory, whereas this is not the case in the field. When Poisson's ratio is 0.25 the amplitude ratio of longitudinal to traverse waves is

$$V_L / V_T = (1 - \sigma)/(\tfrac{1}{2} - \sigma) = \sqrt{3}$$

However, the ratio measured in the field ranges from about three to twenty. Hence the transverse waves are much less important in the field than in model experiments. The weathered layer, being poorly compacted, also acts as a filter for transverse waves. It is difficult to represent the weathered layer satisfactorily on a model.

4th to 6th June - Geografrance weight-dropping party, Gafsa, Tunisia.

Personnel of the weight-dropping party consisted of 13 staff men, mainly Europeans, and 50 indigenous labourers. Accommodation for the staff was in large caravans. These included mess, office, laboratory, sleeping cabins, and ablution unit.

Seismic work using explosives had previously been done in the survey area, with practically no usable results. The terrain was hilly and sandy to stony. It was frequently quite rough owing to bad erosion, but little difficulty was experienced in operating the weight-drop truck under such conditions. Two patches each of 288 geophones were used. There were eight dropping stations every 400 metres and drops were made in a circle of 50-metres diameter around each station. Twenty-four drops were made for each station. Special drops were made every 25 metres along the profile, using low-frequency geophones, to record shallow refraction events for weathering information. Progress rate was about 2 km/day, somewhat slower than normal because of the rough terrain.

In the recording truck a McCollum Geograph tape drum with two magnetic tapes and two electro-sensitive paper records was employed in conjunction with SIE GA-11 seismic amplifiers and FM modulators. The signals thus obtained on the original tapes were transferred in the field to a storage tape using six transfer heads. In this process six traces, resulting from six separate drops, were read simultaneously by means of the transfer heads and composited to produce a single trace on the storage tape. The positions of the six transfer heads were adjusted by means of levers to correct for the weight drop time, which varied slightly from drop to drop. Further compositing was done to the extent required in a central analysing office. No further reduction of data was done in the field. Recording was done using a 24 to 60 - c/s filter. There was

Figure 12 Marine seismic cable at stern of CGG recorder boat, Sicily

Figure 13 'Spudder' percussion drilling, Po Valley, Italy. Percussion weight hitting drill pipe.

Figure 14 'Spudder' percussion drilling. Photograph shows tackle for withdrawing drill pipe supported by a large 'A' frame. Firing line is seen protruding from drill pipe no further filtering during compositing. Reflection results being obtained were of poor quality but superior to those obtained previously using explosives.

8th to 11th June - CGG marine seismic party, western Sicily

The CGG marine crew that I visited was a conventional crew using two boats of 130 and 170 tons. The CGG seismic personnel consisted of a party leader, observer, junior observer, recording assistant and shooter. There were about 12 other men making up the ships' complements. Seismic amplifiers, TI type 7000B with prefilters, were used in conjunction with a Magnedisc recorder. At the time of the shot the record was displayed on a Variable Intensity Plotter (VIP). At night the day's recordings were played back on the VIP. Dynamic corrections were applied during this process, the results being registered on film. Photographic enlargement of the film was done next morning to provide provisional cross-sections.

Location of the shot-points at sea was done using a radio-navigational system ('Toran') built by CGG. There were four or five radio beacons on land. Beacons in each of two pairs of beacons emitted signals differing in frequency by 80 c/s. On the recording boat beats were received at a frequency of 80 c/s, the phases changing as the position of the boat changed. Readings were taken on two phase meters on the bridge. The phases were all pre-calculated for the different shot-point positions. The recording boat, with geophone cable attached, was stopped briefly during the firing of each shot and the position of the shot relative to the spread was found accurately from 'water breaks'. Shots were fired every three to four minutes.

12th to 15th June - Agip Mineraria, Milan, Italy

Agip Mineraria, a large corporation owned by the Italian Government, has a very large establishment near Milan where its oil exploration, production, research, and administrative sections are grouped together. While visiting Agip I spent the greater part of the time with the seismic exploration, interpretation, and research departments but also had the opportunity to see something of the research and developmental projects being undertaken in the geological and petroleum technology sections.

One day was spent visiting an Agip seismic crew working in the Po valley about 50 miles from Milan. The recording equipment used was of simple, conventional type without magnetic recording. Excellent reflections were being obtained although only two geophones per trace were employed. Perhaps the most interesting feature of this party was the shot-hole drilling. Because of the frequent occurrence of sand and gravel in the Po valley, drilling by conventional rotary rigs is very difficult. In this region Agip use exclusivly an arrangement known as the 'Spudder'. This is a simple percussion type of rig with which casing is hammered into the soft ground with a conical piece of steel on the lower end (Figures 13 to 16). The depth of shot-holes is usually about 20 metres. The shot is fired while the casing is still in the ground and then the casing is withdrawn by means of an A-frame and winch. The steel cone at the bottom of the casing is not attached and is not recovered after the shot. Drilling by this method was extremely rapid and the equipment used was relatively cheap.

Figure 15 'Spudder' percussion drilling. Note guiding rod and striking plate for percussion weight.

Figure 16 'Spudder' percussion drilling. Charge being loaded inside drill pipe. Tackle is ready for withdrawing pipe after shot.

In the processing of seismic data Agip places much emphasis on the production of migrated depth cross-sections. A catalogue of time/depth/velocity curves is kept for all areas that have been worked, and sets of curves have been drawn up for a large range of likely conditions to give values of depth, displacement, and tan θ required for curved-path plotting. When extensive seismic surveys are done in areas where the velocity distribution cannot be represented by a suitable mathematical equation, wave-front charts are drawn.

The seismic research section of Agip Mineraria was small, but competent and enthusiastic. The main project under study was the development of an automatic system which, starting from uncorrected magnetic tapes, would apply corrections, select reflections while rejecting noise, and plot the reflections on a depth cross-section in their correct migrated positions. This will involve digital recording or sampling of normal tapes and the use of an electronic computer.

18th to 22nd June - Societe de Prospection Electrique (Schlumberger), Paris

During this week I attended 30 hours of lectures on theory and interpretation of electric logging, including sonic logs. The knowledge gained should prove useful both from the point of view of general geophysical education and for correlation of seismic results with other subsurface geophysical information.

25th to 29th June - IFP and Schlumberger, Paris

Most of this week was spent at the IFP studying the currently-used IFP playback centre and also the new playback system that the IFP had in an advanced stage of construction. The playback system currently used at the time of my visit consisted essentially of a Magnedisc, a Carter tape drum, an SIE tape drum, modulators and demodulators required for these tape systems, a 'Seismac' computer for applying corrections, a set of 7000B seismic amplifiers, a delay line filter, and a camera. This system had been in operation for a number of years and had given good service, although it was admitted that the 'Seismac' was subject to fairly frequent breakdowns.

The new playback system had been designed to give greater versatility and greater speed of operation in performing many functions, such as stacking of tapes, mixing and filtering, etc, and also in the production of record cross-sections. The main feature of the new system is the multi-drum unit which has, turning on the same axis:

(a) an interchangeable drum to take SIE or Carter field tapes. An HTL Magnedisc can also be synchronised with the drum system,

(b) thirteen Carter-type tape drums for use in multiple coverage or other types of stacking operations,

(c) a special drum for a narrow magnetic tape storing a programme of variable gain or for use in synthetic seismogram operations,

(d) a special drum equipped with a photo-electric cell reader for a transparent photographic film to perform similar operations to (c).

(e) two special photographic drums, each 40 cm wide and capable of taking up to about 100 traces (successively) in wiggly line, variable-area, or variable-density form; i.e. multiple coverage cross-sections could be made in variable-area and variable-density forms at the same time.

Each of the 13 drums in (b) has 25 moveable heads for making the necessary static corrections for multiple coverage or other applications. At first, dynamic corrections will be made by means of the 'Seismac' but it is expected that this will eventually be replaced by a better system.

Another important feature of the system is a group of 50 magnetic delay lines for use as time domain filters. These will be used for elimination of 'ghosts' or 'singing', for very-narrow-band filtering, and for 'oblique mixing', etc. With 50 delay lines and two photographic drums it will be possible to do two types of filtering and two types of photographic display simultaneously. Facilities for many types of mixing are also provided.

On the morning of 29th June I accompanied Mr M. Konecki of the BMR Petroleum Technology Section on a tour of the Schlumberger workshops and laboratories.

2nd and 3rd July - CGG Montrouge near Paris

On 2nd July I was able to study closely CGG's new CS-621 playback system, which had been designed to replace the Carter MT4 playback units currently in use. The new system was designed to be simple, inexpensive, capable of treating existing problems but adaptable to the addition of further accessories for the treatment of particular problems as they arise. The system, like the IFP playback machines, makes use of pulse-width modulation tape-recording. This type of recording has come to be preferred, after many trials of other types, because recording quality is little affected by variations in quality of the tapes or by variation in tape speed, either on recording or on playback.

The multiple-drum system used in the CS-621 consists of the driving motor assembly, a monitor drum for producing records on electro-sensitive paper, a drum supporting a delay-line tape used in applying corrections, a drum supporting a 'magnetic cam'tape storing velocity information, two drums for Carter-type tapes and a large enclosed drum for photographic recording in variable-area, variable-density, or wiggly-line display. The basic playback unit is capable of applying a large range of static corrections and dynamic corrections according to any velocity distribution and for any spread length. Mixing can be carried out on up to four traces.

Among the optional units that can be added to the basic equipment are (a) a transcriptor which permits the direct processing of any type of field tape, (b) two extra Carter-type drums to facilitate simultaneous stacking of four records, compositing up to nine traces and multiple coverage, and (c) a device for producing magnetic tapes from old photographic records.

On 3rd July I was shown some of CGG's research projects. The most interesting of these was the vectorial cross-section, which has reached the stage of commercial exploitation and which appears to have great possibilities. On this type of electronically-produced cross-section only the reflections are shown, all noise being eliminated. The vectorial cross-section resembles a hand-plotted cross-section but the subjective element of picking and grading reflections is totally eliminated. Each reflection 'leg' is shown as a black line whose thickness depends on the grade of the reflection.

The essential feature of the equipment for producing vectorial cross-sections is a device for cross-correlating a number of traces to determine the coefficient of resemblance between traces at a given time. By means of a trace selector, four traces are selected and read from two adjacent corrected tapes on a tape transport drum. These traces may be adjacent or, alternatively, only every second or third trace may be selected. The traces selected are passed through amplifiers with AGC and then through electronic delay lines. The amount of delay suffered by each trace is adjusted according to the dip value under consideration. For instance, if it is desired to use the equipment to pick horizontal reflections, with zero dip, the delays between the four traces selected are made equal and cross-correlation is performed between the traces at equal cross-section times. The coefficients of resemblance so determined regulate the intensity of a horizontal line on a cathode ray tube, the intensity of the line varying with cross-section time and increasing greatly at any time when a horizontal reflection or other phase line-up occurs. The line image on the CRO tube is transferred optically onto a rotating photographic drum. When picking of horizontal line-ups is completed for the four traces under consideration the delay times on the four delay lines are changed so as to sample sloping events corresponding to a specified value and direction of dip. At the same time the line or 'vector' on the CRO tube is rotated a corresponding amount and, as the photographic drum rotates, dipping vectors are recorded on the same track as was previously used for horizontal events. This process of recording successively on the same track is repeated for a number of discrete values of dip. In practice those events with dips between two of the discrete values selected are recorded at reduced intensity on each of the sweeps for adjacent discrete values. The intensity is increased on the photographic record by superposition and thus all values of dip are recorded equally providing the sampling interval is well chosen.

Of course it is possible to produce cross-sections showing only vectors with dips between selected values. Such cross-sections may be very useful in examining profiles on which reflections dipping in different directions are superimposed and hence confused. Similarly diffraction patterns may be separated from true reflections in some cases.

<u>4th to 6th July - CGG Reflection Party 1319, Romans, France</u>

The CGG reflection party visited was working in a difficult area bordering the Alps in south-eastern France. As was the case with most CGG reflection parties, this crew was equipped with Carter FR1 recording equipment and EVSL geophones which were used 24 per trace in line with five metres between geophones. Drilling was done in a fairly conventional manner by means of two Failing 1500 rigs using mud circulation. Because of the problem of hole-caving due to the presence of sand and gravel it was generally necessary to case the shot-holes. Often the casing itself was used for drilling instead of the normal drill pipe, a cheap, expendable bit being used and left in each hole.

The party's main problem was connected with weathering. The elevation profiles along the seismic traverses showed very marked changes with which were associated large variations in surface layers. Shot depth was very critical. It was necessary to place the charges in, or below, a certain layer in which the velocity was 2300 ft/sec. For this reason the party was supplied with an auxiliary shallow-refraction team which worked in advance of the drills in order to determine optimum shot-depth. Personnel for this team consisted of one geophysicist, one shooter, one driver, and two labourers. They normally worked about half of their time in the field. For the rest of the time the geophysicist carried out the interpretation of the shallow-refraction records while the other four men were engaged on extracting casing from used holes by means of a Dodge power wagon with A-frame and winch. The refraction team used SIE P11 recording equipment, considered obsolete for normal reflection work, and 8-c/s Century geophones. Computational methods used for the shallow refraction work were essentially the same as those employed by the BMR.

9th to 11th July - CGG central playback office, Paris

During this time it was possible to study all aspects of the CGG playback centre. The Paris central playback office had in current operation three Carter MT4 playback systems, a transcripter built by CGG for handling SIE and Techno tapes and Magnediscs, a Techno Decatrack, and an EIC Transcorder for producing magnetic tapes from old wiggly-line records.

The Carter MT4 playback system had been extensively modified by CGG. Most of the electronic circuits had been replaced by CGG - designed and built circuits. In addition, the original analogue device for providing dynamic corrections had been modified by CGG to provide a reasonable approximation to any desired velocity function, instead of being restricted to constant velocities as originally. The MT4 was considered reliable and generally satisfactory by CGG. Its chief disadvantage in the modified form appeared to be its slowness in producing cross-sections. The three CGG machines in Paris were operated 24 hours a day.

The Decatrack was not used a lot by CGG because most of its field crews used Carter-type tapes which needed to be transcribed to Techno-type tapes for use on the Decatrack. It is used in some cases where stacking of large numbers of tapes is required. The main disadvantage of the Decatrack appears to be the high-frequency noise that is introduced to the tapes as harmonics of the signals. For this reason CGG finds that it is inadvisable to pass tapes through the Decatrack more than three or four times. It is also found that the Decatrack heads need to be aligned frequently and with care.

The EIC Transcorder worked quite successfully. The wiggly-line record traces were followed with a spot of light moved by rotating a potentiometer knob as the wiggly-line record rotated on a drum. Transcription to magnetic tape in this way was rather slow. About an hour and a half was required for reproduction of a 24-trace record 3.5 seconds long, but the machine could be operated by a non-technical operator.

12th and 13th July - IFP, Paris

These days were spent at the IFP studying inverse filtering, including applications to marine seismic work, e.g. the removal of 'singing' from marine records.

At this time I was also able to examine the completed version of an IFP-designed set of transistorised recording equipment, the 'Sismistor', and to study the results of field tests of this equipment. The Sismistor was designed as a very flexible, high-quality instrument for use by the IFP experimental crew, As the Bureau may have similar requirements for equipment in future the following details of the Sismistor are given:

Amplifier pass-band. The amplifiers will pass frequencies down to 5 c/s when using AGC or 2 c/s without AGC.

Gain programme. The shape of the gain curve is adjustable by potentiometers at three different times on a record and these adjustment points can be moved up or down the record as required. There is a gain difference of 51 db between the first and third adjustment points and after that the gain increases at a constant rate of 6 db per octave time.

Automatic gain control. AGC has a dynamic range of 60 db on top of gain programme. Amplifiers can accept 100 millivolts input without saturation.

AGC Settings	Compression time (msec)	Expansion time (msec)
1. slow	1900	300
2. medium	300	100
3. fast	100	30

Equipment noise level. 0.1 microvolt.

Temperature variation. Two percent at 60°C in laboratory tests.

Camera and magnetic recorder. The same IFP camera can be used to record wiggly line, trace by trace, on electrosensitive paper, or by galvanometer on photographic paper, or to record variable-area on photographic paper. A Carter-type tape with pulse width modulation is used for magnetic recording. The playback head on the tape drum is moveable to enable production of statically and dynamically corrected records in the field.

Current drain. Three amperes on 'record', five amperes on 'playback'.

Price. It is expected that the 'Sismistor' will be built and sold commercially by CGG. The price is expected to be similar to that of other transistorised sets on the market.

Initial field tests showed that the Sismistor compares more than favourably with the HTL 7000B set in performance.

16th to 24th July - CGG, Paris

The first three days were spent studying refraction interpretation with two of CGG's specialists, Messrs Clement and Layat. The main emphasis of this study was on the picking of events, recognition of faults, and selection of field parameters to obtain the most useful records. This study was a very useful adjunct to the more routine study of the refraction method made earlier in the field.

For the remainder of the time I studied the production and interpretation of synthetic seismograms with one of CGG's specialists in this subject. I was also able to see a number of examples illustrating the usefulness of synthetic seismograms.

25th to 27th July - Shell and Hall-Sears, The Hague

On 25th and 26th I visited the Battafse Internationale Petroleum (Shell) company at the Hague where I was able to have lengthy discussions with several Shell geophysicists on all aspects of seismic work, including noise testing and analysis.

On 27th I visited the Hall-Sears organisation where I saw the manufacture and testing of a number of types of geophones and discussed trends in geophone development with the manager, Mr Vitringa.

30th July to 1st August - Seismos and Prakla, Hanover

The 30th July was spent visiting the Seismos company in Hanover. This private contracting company manufactures most of its own field seismic equipment. I was shown the laboratories, workshops, central playback office, and also some of the German-made shot-hole drilling equipment used by Seismos. This company has had a considerable amount of experience in recording large explosions at distances of up to several hundred miles, and manufactures special low-frequency refraction geophones for this type of work, which are sold commercially. Radio transmission of geophone signals to the recording equipment has been used successfully. Seismos operates about 13 seismic crews.

On 31st July I visited the Prakla company, which is government-owned but which operates commercially in competition with Seismos and other companies. Prakla also manufactures most of its own field seismic equipment but, unlike Seismos, it sells none of this. The equipment appeared to be of particularly high quality. Prakla had an efficient playback centre in which Carter MT4 equipment was used for the routine work. A more flexible unit had also been designed and built by Prakla for experimental work. This incorporated a 24-trace oscilloscope enabling rapid evaluation of the effects of varying filters, AGC settings, etc. when playing back a tape. Prakla had their own Elliot electronic computer. They had prepared a programme for computing data for curved-path plotting of reflection results, allowing for up to ten velocity discontinuities. It is intended to use this for future computing of migrated cross-sections. Prakla operates about 30 field crews including two marine seismic crews.

On the morning of 1st August, following the recommendation of Dr Maass of Prakla, I visited the Federal Institute for Ground Research (Bundesanstalt für Bodenforschung) in Hanover. This is a government-sponsored organisation which attempts the solution of various geological, geophysical, and mining problems in Germany and some underdeveloped countries.

The Institute does not run its own seismic crew but sometimes participates in experimental work using a contract crew. It had, for instance, experimented with refraction recordings at sea during the course of a marine reflection survey made by Prakla and also investigated variations in water velocity. One of its main fields of investigation is the crustal structure of the Earth and, like Seismos and Prakla, it has participated in the recording of many large quarry blasts in Germany. Another field in which the Institute is very active is hydrology, since water is in short supply relative to the large needs of the country. Determination of the ages of water deposits is something which the Institute has investigated and which might be of great importance in Australia. It is my impression that the Institute would be very willing to co-operate with the Bureau in studying mutual problems and in supplying technical information.

2nd to 8th August - BP, London

During this period I visited the central office of BP in London and also the company's research establishment at Sunbury near London. At the central office I discussed with company geophysicists refraction work and seismic work in general and saw the central playback office (CPO), which was equipped with a Carter MT4 playback system and an Omnitape machine. Perhaps the most interesting feature of the playback centre was a device for automatically setting the static and dynamic corrections on the MT4. These corrections were computed in the field and the corrections for a single tape were recorded on a special card as pencilled dashes on printed scales. The cards were sent to the CPO with the tapes and as each tape was processed the appropriate card was placed on a reading machine which translated the position of the pencilled dash for each trace into the required correction. This correction was set automatically on the playback machine. At the Sunbury research establishment the most interesting piece of seismic equipment under development was a geophone tester. This was a compact unit incorporating the necessary equipment for applying the well-known ellipse test for checking the performance of geophones.

9th to 14th August - SSL, London

This period was spent visiting SSL's headquarters near London and also an SSL reflection crew working in Kent. I was shown a number of interesting items of equipment by SSL. The most important of these was the vibrator for the 'Vibroseis' system developed by Continental Oil Company in America and used under licence by Seismograph Service Corporation and its subsidiary company SSL. In the 'Vibroseis' method a continuous seismic signal of varying frequency is injected into the ground by means of a vibrator. The reflected signals are recorded using conventional geophones, seismic amplifiers in which little filtering and no AGC are required, and a drum-type magnetic recorder. The original injected signal is then cross-correlated with the reflected signals to produce a record that closely resembles a conventional seismogram. Both hydraulic and electromagnetic vibrators had been tried as sources but it appears that the electromagnetic type has proved most successful. This type is in principle similar to a large geophone working in reverse and capable of exerting a thrust of several tons on the ground surface. The vibrator unit which I saw working had two vibrators mounted several feet apart on a special trailer towed behind a tractor which was equipped with hydraulic equipment for rapid raising and lowering of the vibrators. The large amount of electrical power required to drive the vibrators was generated by two alternators driven by the tractor engine. Each vibrator required 100 amperes at 96 volts.

SSL's optical system for producing corrected variable-area cross-sections was also of interest since this provided most of the advantages of magnetic recording but was very much cheaper both in the initial cost of equipment and the cost per cross-section. The playback unit processes variable-area records taken on high-contrast photographic paper. The tracks are illuminated and scanned by heads incorporating a light source and a photo-diode. The light reflected from the individual traces is converted photoelectrically to electric signals which can be recorded in a camera or any kind of cross-section plotter. Static and dynamic corrections are applied by movement of the photoelectric heads. The velocity function for the dynamic correction can be set to any desired value on a flexible band on the side of the unit. Spread length is taken care of by means of (a) the cams controlling the movement of the photo heads and (b) the gearing between these and the rack which is controlled by the rotation of the flexible band. Playback is simultaneous on 24 traces. The signal circuits of the playback unit are fully transistorised; ordinarily they connect directly to the variable-area or variable-density recording units without the need for seismic playback amplifiers. At the commencement of a new survey the system may be used to make filtering studies. In this case, the observer shoots fairly wide-band records; provision is made to replay these through the variable-area playback unit and the conventional seismic amplifiers to the display unit.

SSL also had a variable-area cross-section recorder which was notable for its small size and speed of operation. To avoid using a rotating photographic drum, which would occupy a considerable volume, the recording film was kept stationary on a curved surface while the light beams, which write the 24 traces simultaneously, were swung through an angle of about 90 degrees. The dimensions of this cross-section recorder were about two feet by two feet by one foot. The film used was 9½ inches wide by up to 100 feet in length, and the image width of 24 traces was 2/3 inch. There was virtually no limit to the length of cross-section which could be produced on film. The unit could be used in conjunction with a DS-7 or similar type of magnetic recorder, as well as the SSL optical playback unit.

The SSL field crew I visited in Kent was somewhat unusual in that most of the field vehicles were tractors fitted with four-wheel drive. These vehicles were well-suited to the muddy farmland conditions encountered by the crew, were more manoeuvrable than trucks in confined spaces gateways, etc., and were more readily allowed access by farmers than trucks. The recording vehicle was a tractor that had a single cab for driving and recording, a swivel seat being used for both purposes. The recording equipment was mounted at the rear of the cab. Two small drills were also mounted on the backs of tractors, as also were upright, cylindrical water tanks holding about 400 gallons.

15th August - Geophysical Service International, London

Visits were made to GSI's head office in London and also its playback and interpretation centre. The latter was mainly concerned with processing of GSI marine work in the eastern hemisphere. The playback equipment was essentially a set of 7000B amplifiers, a special cam console for applying corrections, and an EIC drum unit capable of handling SIE or Techno-type tapes.

4. CONCLUSIONS

The programme followed during the six months of the tour proved to be most valuable. It is considered that the greatest gains in knowledge were made in those subjects whose study were set as the specific purposes of the visit, viz. seismic noise and large-scale seismic refraction work. The first subject was studied with the Institut Francais du Petrole, which has done several years experimental work devoted to reaching a thorough understanding of noise measurement and elimination; the seismic refraction techniques were pursued with the Compagnie Generale de Geophysique, which has a formidable **reputation** for success and innovation in this field. Although the greater part of the tour was spent with these two organisations, visits to a number of other geophysical organisations allowed comparison of methods used and conclusions reached by a number of independent workers. In this way it was possible to draw on a large amount of varied experience.

REFERENCES

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