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BUREAU OF MINERAL RESOURCES GEOLOGY AND GEOPHYSICS.

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NOTES ON OVERSEAS TRIP TO SUMATRA AND THE MIDDLE EAST SEPTEMBER-DECEMBER, 1961.

by

E.J. Malone.

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by

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INTRODUCTION

This report briefly outlines my overseas study trip which was authorized by the Commonwealth Government as a means of training officers concerned in various aspects of oil exploration.

The main purpose of my trip was to study geological and geophysical techniques employed in oil exploration, the presentation and interpretation of results, and the co-ordination of geological and geophysical data. A secondary aim was to study well logging techniques, mainly from the point of view of evaluating well data and correlating well and outcrop information.

To see as many exploration techniques as possible I visited established oil fields, newly discovered fields and as yet unproductive areas of exploration in nine countries and as many geological environments. My itinerary was as follows:

September 22 - October 5	Caltex Pacific Oil Company, Central Sumatra, Indonesia.
October 10	Bahrain Petroleum Company, Bahrain.
October 11 - October 12	Petroleum Services (Middle East) Ltd., Bahrain.
October 12 - October 14	Qatar Petroleum Company, Dukhan, Qatar.
October 15 - October 17	Petroleum Development (Tracial Coast) Ltd., Tarif, Abu Dhabi.
October 17 - October 19	Abu Dhabi (Marine Areas) Ltd., Das Island.
October 19 - October 20	Qatar Petroleum Co., Umm Said, Qatar.
October 21 - October 22	Petroleum Services (Middle East) Ltd., Bahrain.
October 23 - October 27	Kuwait Oil Company, Kuwait.
October 29 - November 8	Iran Oil Operating Companies, Iran.
November11 - November18	British Petroleum Exploration Co. (Libya) Ltd., Benghazi, Libya.
November19 - November25	American Overseas Petroleum Ltd., Tripoli, Libya.
November28 - November30	Compagnie de recherches et d'exploitation de petrole au Sahara (CREPS), In Amenas, Polignac Basin, Algerian Sahara.
December 1 - December14	Societe pour Prospection du petrole d'Alsace (PREPA) Djado Basin, Niger.

I wish to acknowledge my thanks to the various companies for permitting me to visit their operations. I am very appreciative of the kindness, hospitality and valuable instruction I received from the staff of these companies. Personal letters of appreciation have been sent to all companies and organizations visited.

I am grateful to the Commonwealth Government for financing the trip and to the Bureau of Mineral Resources for selecting me. I am very grateful to Dr. N.H. Fisher and Mr. L.C. Noakes who used their personal contacts to arrange much of the trip.

SUMATRA

Caltex Pacific Oil Company

Caltex Pacific Oil Company is producing oil from the Duri and Minas fields. Several other pools are known but are not yet fully tested. Further exploration is held up awaiting the outcome of negotiations with the Indonesian Government on the future of foreign-owned companies in Indonesia.

The oil in Central Sumatra is contained in a Tertiary sequence about 7,000 feet thick, on a basement of metamorphosed Palaeozoic/Mesozoic rocks. The initial exploration consisted of geological mapping of available outcrop in the field area, which is largely swamp covered, and intensive mapping in the foothills of the Barusan Mountains to the south-west where the Tertiary sequence is well-exposed. The first discoveries were located as a result of surface mapping. They were pools associated with large anticlines reflected in the topography as well as the geology.

Since 1949, when exploration resumed after the second World War, there has been some geological mapping, mainly for stratigraphic information. In this period, seismic surveys have been the main exploration tool. The technique employed is in-line reflection shooting with overlapping split spreads. Some minor modifications have been developed to handle the particular problems of operating in swamps. This seismic work is very expensive, due to the terrain, but the results are reasonably good. The seismic results are produced in the "squiggle" section presentation form. They are interpreted by geologists of the exploration staff, who have done special courses in geophysical interpretation, or else they have had on-the-job training.

Gravity surveys were commenced more recently; the readings were made along the seismic lines. They have produced good results due to the relatively shallow depth to the denser Palaeozoic/Mesozoic basement which is apparently involved in the Tertiary fold structures. The results indicate that gravity surveys, prior to the seismic surveying, would probably have saved the company money by reducing the total area of seismic surveying. In general, the gravity results are presented as a Bouguer anomaly map. Selected areas are studied by producing residual gravity maps.

Well logging includes production of a percentage cuttings log as a first step. A descriptive lithological column is compiled from this with the formation breaks located by comparison with the Schlumberger logs. The stratigraphy is controlled by palaeontology, mainly based on foraminifera, and by comparison with outcrop sections.

Electric, micro and micro-caliper logs are run in most holes. Gamma ray/neutron and induction logs are run in holes drilled with oil-base mud. The electric log, or the gamma ray/neutron are used to locate the oil water contact. The micro-log and micro-caliper are relied on to indicate permeable zones. Some attempts are made to determine porosity by quantitative interpretation of the micro-log. This is difficult because of the poor consolidation of the Tertiary sequence, which also reduces the value of the neutron log. The definition of the gamma ray curve is reduced by the high proportion of clay in the sandstone beds.

In order to appreciate the reliability of the various well logs, I spent several days comparing samples and cores from two frequently cored wells with the composite log and Schlumberger logs. Most of the problems of interpretation were possibly due to the difficulty of working in poorly consolidated sediments.

PERSIAN GULF AREA

Bahrain Petroleum Company

The Bahrain Petroleum Company field on Bahrain was the first visited in the Persian Gulf area. It is a fully developed field, producing about 45,000 bbls/day from 150 producing wells. The pool is in a simple anticline outlined at the surface by both topography and geology and located by surface mapping. It was the first discovery in the Persian Gulf area.

Petroleum Services (Middle East) Limited

Much of my time in the Persian Gulf area was spent with Petroleum Services (Middle East) Limited, (P.S.M.E.) a subsidiary of Iraq Petroleum Company. It operates as an oil exploration group in the I.P.C. concessions outside Iraq. In addition it supplies technical and other services to Qatar Petroleum Company and Petroleum Development (Trucial Coast) Limited, two other subsidiaries of I.P.C. which I visited.

Since the 1930's, the exploration group of I.P.C. has explored for oil in a number of large concessions covering parts of Saudi Arabia, the Trucial States, Omen, Muscat, the Aden Protectorate and Dhofar. P.S.M.E. was formed from this exploration group. Its techniques are those used and developed in the exploration of these very large and initially little known areas. Essentially, a regional stratigraphic study is the basis of their exploration programme. The first stage includes photogeology and surface mapping, and studies of the basement, basement tectonics and the tectonic framework of the sedimentary basin. Within the sedimentary basin, field work consists mainly of detailed section measuring and sampling. Formation boundaries are mapped in the field, where necessary, or photo-interpreted after the geomorphology of the unit is known. Accurate formation mapping is of less importance than gathering stratigraphic information. (This is in contrast to the Bureau's approach. Our prime function as a regional mapping organization underlies and affects every specific undertaking).

Samples are collected from every three feet of section. The measured sections are compiled as columns in the field, with lithological descriptions and sample numbers. At monthly intervals, the samples and columnar sections are sent to the exploration base office. There, all samples are thin-sectioned and examined by a sedimentologist and a palaeontologist. Modifications to the field stratigraphy are made at the end of the field season by the field geologists and specialists in consultation. This usually involves re-examination of important samples. The field party receives the assistance of two specialists who are sufficiently available to handle the work, as well as technical assistants to process the material.

Geophysical work may commence at the same time as, or may follow, the geological mapping. In southern Arabia, airborne magnetometer surveys were flown in the first year. Much of this area is sand-covered and the magnetometer surveys outlined the areas underlain by basement rocks. This airborne work was followed by ground gravity/magnetometer surveys, reconnaissance seismic and then detailed seismic work in selected areas. The geophysical work is mainly to delineate structure. In some cases, geophysical work, particularly refraction seismic, is undertaken to outline the basement slope where such knowledge can assist in facies and stratigraphic studies.

The results of the regional stratigraphic study are used to assess the seismic structure contour maps, particularly to locate coincidence of structure and favourable facies. On this basis, the initial explanatory hole is located. All holes are located primarily to test for possible accumulations. However, the company appreciates the importance of the stratigraphic information obtained by drilling and is willing to accept higher drilling costs in order to extract the maximum information.

When it decides to drill, the company practice is to review the stratigraphic and structural information on which the site was selected and prepare a prognosis of the well. Any fossiliferous bands, marker horizons or seismic reflectors are located on this prognosis.

In exploration wells, cores are cut every 200 feet, approximately, at formation breaks, throughout potential reservoir horizons and at various pre-determined stratigraphic horizons. The latter may involve continuous coring for some distance to be certain of coring the target horizon. Thin sections are made of cuttings samples, collected from every 5 feet of hole. These thin sections are examined by a sedimentologist and a palaeontologist.

Once the well is completed, the information gained is incorporated in the regional stratigraphic study. This may involve anything from minor reassessment, if the results of the well compare closely with the prognosis, to a complete re-interpretation of all stratigraphic data.

These exploration techniques are illustrated by the work in Southern Arabia, where I.P.C. hold adjoining concessions in the Aden Protectorate, Dhofar, Muscat and Oman. There, the company was able to rationalize their exploration programme by treating these areas as a single part of the Persian Gulf Geosyncline. Political pressure from the various rulers prevented them doing this in the Trucial States where they were forced into a piece-meal attack.

In Southern Arabia, exploration continued from 1952 to 1960, culminating in the drilling of four exploratory wells during the last few years. The four holes were dry but the information gained from them indicated the direction in which exploration should continue. In 1960, two of the partners in I.P.C., Shell and Partex took over most of these concessions and are continuing exploration along these lines.

Some geologists, mainly with American companies, consider this exploration approach too slow. Certainly, the "find a structure and drill it" technique has proved successful in the immediate vicinity of the Persian Gulf, but this is an amazingly oil-rich area. The American company which took over the I.P.C. concession in Dhofar in 1960 has since drilled about 20 dry holes. In Australia, where results already indicate that oil will not be discovered easily, the exploration techniques of I.P.C. have much to recommend them. The I.P.C. exploration group, Petroleum Services (Middle East) Ltd., is organized to produce close co-operation between geological and geophysical personnel. This is evident in their method of interpreting seismic results. The initial interpretation is made by the geophysicist and geologist together, on "variable area" section presentation records. The purpose of this is to extract the maximum information from the records, including second order information. The final interpretation is made by the geophysicist using "squiggle" section presentation records. Meaningful reflections are more obvious on the "variable area" record but, once recognised, can be picked more accurately on the "squiggle" records.

Dukhan Murban and Das Island fields

I visited two fields operated by companies connected with P.S.M.E. The first was the Dukhan field in Quatar. This is a simple, elongate anticline containing three producing horizons, discovered as a result of surface mapping. Subsequently, gravity and seismic surveys were run over the remainder of Quatar. No structures were located and the horizons producing at Dukhan were water flushed in three exploratory wells drilled.

The second was the Murban field, near Tarif in Abu Dhabi, one of the Trucial States. This field and its extension, Murban West, were in a very early stage of development. Only nine holes had been drilled at the time of my visit. This area is mainly covered by Quaternary sand cover. The structure was located by seismic work, following a detailed gravity and magnetometer survey. While at Murban, I saw something of the duties of the well-site geologist and discussed them with him. These duties were fairly standard. The well-site geologist was required to write the following reports:

(a) Weekly. This contained the percentage lithologic log, based on cuttings, and detailed lithological descriptions, as well as noting accessory minerals, fossils, organic remains, bitumen or oil staining, fluorescence, etc.

(b) Monthly. This summarises the lithological descriptions of the weekly reports and expands on stratigraphy, correlation, structure, etc. It should contain the composite lithological log for depth of hole drilled.

(c) Completion. This is written in conjunction with the Petroleum Engineer and includes an assessment of the well's potential. It contains a review of the subsurface geology in relation to the well, and notes any variations from the prognosis, and includes the complete composite log with formation boundaries by using the Schlumberger logs. In the Murban field, the S.P. and Sonic logs give excellent results and are included on the composite log.

The only other field visited in the Persian Gulf was the off-shore field near Das Island, operated by Abu Dhabi (Marine Areas) Ltd. This company is owned by British Petroleum Limited and the Compagnie Francais des Petroles. The field is in a large, shallow dome discovered by marine seismic. At the time of my visit, the drilling barge was being moved to the site of the seventh well.

KUWAIT

Kuwait Oil Company

The Kuwait Oil Company is producing from what is probably the largest oil pool in the world. Their three main fields Burgan, Magwa and Ahmadi are parts of a continuous reservoir. The oil column is about 1200 feet high, which is approximately equal to the closure on the structure. The vast reserves of this field are due to the size of this shallow structure and to the very high porosity of the producing sandstone, the Burgan Formation. The permeability of this formation is estimated to be 4 to 5 darcies.

There is little surface geology in Kuwait. The initial surface mapping noted three oil seeps and one anticline. Subsequently, gravity, magnetometer and seismic surveys outlined the Burgan structure. The first test of this structure was drilled in 1937/38 and proved successful, but major development did not commence until 1946.

In Kuwait, I spent some time examining cores and samples to get an idea of the sequence. I studied the various logs run by Kuwait Oil Company and discussed the reasons for using these logs. The logs run are:

(a) Electric log. (Self potential and three resistivity curves) for correlation, demarcation of sand bodies, oil/water contact and ready assessment of well potential.

(b) Latero-log. A focussed, deep penetration tool giving true resistivity, particularly of thin beds, and definition of the oil/water contact where obscured by alternating sand and shale lenses.

(c) Gamma ray/Neutron log. For demarcation of sand bodies, estimation of shale content in sandstone, correlation, porosity evaluation and in some cases gas/oil contact.

(d) Caliper survey. For correction of hole effects on Gamma ray/Neutron log and possibly on Laterolog, and for petroleum engineering department.

(e) Micro-laterolog. For quantitative determination of residual oil saturation and for determination of porosity.

The company has run the Sonic log in a number of wells, but the results were not satisfactory. The instrument is delicate and mechanical breakdowns are common. Also, the log is affected by the poor consolidation of the sediments and the presence of shale and fine grained matrix in the sandstone. The poor results with the Sonic log in Kuwait are in marked contrast to the excellent results obtained in the Murban field.

IRAN

Iran Oil Exploration and Producing Companies

The oilfields of Southern Iran are operated by the Iranian Oil Exploration and Producing Companies, an association of 16 international oil companies, which came into being in 1954, three years after Iran nationalised its oil industry. Prior to that date, the fields had been explored, developed and exploited by the Anglo-Persian Oil Company, later becoming the Anglo-Iranian Oil Company. Oil was first discovered in 1908 and is now being produced from seven fields at the rate of about 50 million tons per year. The oil is contained in Asmari Limestone anticlines in the folded belt of the Persian Gulf geosyncline. The structures are tight, with flank dips ofabout 60° (Much steeper than the structures seen in the Persian Gulf area). The closure of these structures is very great; in the Gach Saran anticline, the oil column is 4,800 feet high. Fracturing of the limestone reservoir produces the porosity and a very high effective permeability. The oil is under very great pressure; well head pressures of 3,000 psi. have been measured in some wells. The great pressure and the high effective permeability have resulted in step-out distances of one to two miles or more. The wells are extremely productive. Individual production of more than 40,000 bbls/day are recorded from a few of the Agha Jari and Gach Saran wells.

I.O.E.P.C. has a large geological staff, mainly because strict geological control is needed over every well drilled. This control is needed to avoid disastrous blow-outs, such as have occurred on a few occasions in the past. The problem is to recognise the cap rock above the Asmari Limestone. Both cap rock and Asmari Limestone are folded into simple, tight, in places asymmetrical anticlines. The sequence above this, the Fars Group, consists mainly of incompetent beds and has folded diapirically. Because of the large step-out distances, it is not possible to anticipate the sequence which will be intersected above the cap rock. It may be a straight forward section through the Fars Group or a thrust faulted or over folded repetition of part of the group. A heavy drilling mud is used above the Asmari Limestone to control high pressure water shows in the Fars Group. It is necessary to run casing once the cap rock is entered, to seal off the water shows. Thereafter a light mud is used and extreme precautions against blowouts are taken before drilling into the Asmari. The cap rock is the basal member in the Fars Group. It is fairly distinctive, but similar lithologies occur in the higher parts of the Fars Group. Since the predicted depth of the cap rock may be anything up to 1,000 feet out, in areas of poor structural control, the necessity of strict geological control to ensure its recognition becomes evident.

The duties of resident geologists are set out in an I.O.E.P.C. technical instruction, (Duties of Resident Geologists) a copy of which is attached to this Record. The very strict and detailed instructions set out in this document indicate the importance the company places on strict geological control of drilling operations. I spent several days in the geological office at the Gach Saran field, studying and discussing the resident geologists' duties.

The Asmari Limestone crops out in the cores of several anticlines in southern Iran. Two of these, within 15 miles of Gach Saran field were visited. They provided excellent opportunities to study folded limestone reservoirs, almost identical in shape to the buried oil-filled structures of the producing fields. The crests of these Asmari Limestone anticlines are flat, possibly due to collapse faulting with the development of keystone blocks. The limestone is quite dense in outcrop, is cut by several sets of stylolites and shows no oil staining. The many fractures in the limestone show all stages of solution effect from very little to cavern development. The effects on canyon walls indicate that the present-day solution effects are very great. The unwidened fractures are thus very young, suggesting that the area is still active. There are two sets of fractures in the buried Asmari Limestone anticlines: one set is infilled with secondary calcite and other minerals; the other set is not mineralized and is filled with oil. The mineralized fractures are possibly diagenetic. Oil migration and the second set of fracturing coincided, the presence of the oil preventing any mineralization.

The logging programme in the southern Iranian oil fields is rather limited. Only the Gamma ray/Neutron log is run throughout the hole, as upper hole size is too great for most logs to be effective. Little use is made of the logs in correlation because most holes do not correlate above the cap-rock. On the Agha Jari field the Gamma ray/Neutron log has been run in cased holes. Though the curves are somewhat blurred, they retain sufficient character to permit recognition of gross lithologic units.

A standard set of logs is run in the reservoir interval. It consists of gamma ray/neutron, sonic, micro-lateral, micro-caliper, and laterolog or induction log. The laterolog is run when the drilling mud is salt, the induction log when it is fresh. The neutron and sonic logs are used in conjunction for porosity determinations. Formation resistivity is calculated from the laterolog or indication log and the formation factor is calculated from the micro-lateral log. This company stresses the importance of empirically determining the porosity, permeability and formation water salinity from cores, in order to correct the Schlumberger quantitative interpretation charts for the particular geological environment.

Some surface geological mapping, mainly section measuring, sampling and structure mapping is continuing. The area lends itself to photogeology and this is the main basis of their geological work.

The main exploration tool is seismic work. Initially, refraction shooting was preferred, partly because the terrain was too rugged for reflection work and partly because early reflection work gave poor results. Now, reflection seismic is preferred, particularly as the main area of investigation is the coastal plain which is well suited to reflection work. The technique includes wide frequency recording on magnetic tape, "variable area" section presentation for overall interpretation and "squiggle" section presentation for quantitative travel time determinations. This practice is similar to that adopted by P.S.M.E., as previously discussed.

Refraction work is largely restricted to locating the crests of anticlines. The technique used is arc shooting with the shot point located as near as possible on the axis and the arc at right angles to the axis of the structure. Because of the steep flanks of the structures, penetration effects distort the records where the shot point is located off the axis.

LIBYA

British Petroleum Exploration Co. (Libya) Ltd.

One week was spent with British Petroleum Exploration Co. (Libya) Ltd., with headquarters in Benghazi. The exploration techniques employed by this company are generally similar to those already described. Poor outcrop limits the effectiveness of geological mapping. The main prospecting tool is seismic work, and a variety of techniques have been and are being employed. The quality of reflections varies from extremely good in some areas to very bad in others. B.P. have done refraction work, which is useful for outlining regional trends; reflection seismic including pattern hole and multiple cover shootings; and "thumper" seismic.

"Thumper" Seismic Method

This was the first time I had seen the "thumper" in action. In one area of good reflections, (where conventional seismic would also have produced good results) the "thumper" produced excellent results at the rate of 250 kilometres per month.

In another area, where conventional seismic had failed to produce results, the "thumper" was obtaining reflections by stacking 96 drops per trace. This was slow work, about 40 kilometres per month, but was producing usable reflections.
Attached to this Record are figures showing drop patterns, geophone layout, etc., of the "thumper" system as well as laboratory and field records of the "thumper" compared with conventional seismic.

"Vibroseis" Seismic Method

The "Vibroseis" system was developed by Continental Oil Company. Outside the United States, it is operated under licence by Seismograph Services Corporation who introduced it in Libya during 1961. I did not see "Vibroseis" in operation but discussed it with the Benghazi Manager of Seismograph Services Corporation, and with several of the B.P. geophysicists. Apparently, Seismograph Services Corporation are having some "teething" trouble in their first year of operating this new technique and equipment. However, most geophysicists regard it as a very considerable advance in seismic technique. A particular advantage of the system is that of introducing a known signal into the ground. A number of vibrator trucks can be used at once, as the impact signal is radio synchronized. This permits a great degree of compositing while retaining an acceptable rate of production. Some of Seismograph Services Corporation's circulars, describing "Vibroseis", are attached to this Record.

American Overseas Petroleum at Tripoli

One week was spent with American Overseas Petroleum Ltd., with headquarters in Tripoli. I discussed the company's operations with geologists and geophysicists, and in particular their "strip-map" technique. This was also used by Caltex Pacific Oil Company in Sumatra. It involves selecting a scale, suitable for the particular area being explored, at which all information is plotted. The various types of data are plotted on separate transparent sheets, each sheet covering a strip of the total area. Their practice is to produce a base map, containing essential topography which should not be added to or subtracted from; a cultural map, containing all cultural and geographic data, and subject to amendment; a surface geological map; a photogeological map; a geophysical map showing seismic lines, shot points, gravity stations; geophysical result maps showing seismic contours, Bouguer anomalies, etc. The advantage is that different types of data can be directly compared and compounded. In their Libyan concession, the company has chosen the scale 1:250,000. This technique is well suited to some of the Bureau's sedimentary basin regional mapping programmes. In particular, I hope to apply it to the Bowen Basin survey, compiling all available information at 1:500,000 scale.

At the time of my visit, the General Geophysical Company was doing some conventional seismic work, mainly reflection shooting, for American Overseas Petroleum Ltd. I visited the party with the company geophysicist on his regular weekly inspection visit. The technique consisted of patterns of 9 shot holes per shot point, each with a 5 lb. charge and 24 geophones per patch. Reflections were recorded at an effective filter setting of 19 - 200 cps. and played back at a 27-55 filter setting with 20% mixing of adjacent traces. The high filtering and the mixing sharpened the records somewhat but reflection quality was still extremely poor.

ALGERIAN SAHARA

Three days were spent at In Amenas in the Polignac Basin. The two producing fields, Zarzaitine and Edjeleh, and two fields in an early stage of development were visited. Both producing fields are contained in anticlines closed against faults. The Zarzaitine structure is reflected to some extent at the surface; the south-west boundary fault is reflected as a flexure in the outcropping continental sediments. The structure was indicated by anomalies on gravity and magnetometer surveys but was mainly outlined by seismic survey. This field is the main producer in the Polignac Basin.

The Edjeleh structure is an elongate anticline, about 20 miles long by 4 miles wide. It is outlined at the surface by Carboniferous sediments in conformable sequence with the Carboniferous and Devonian reservoirs. There are three culminations on the structure which is closed against a fault on its eastern flank. The Zarzaitine wells are about 5 times as productive as the Edjeleh wells.

NIGER

Djado Basin

The French company Prepa (Societe pour Prospection du Petrole d'Alsace) is exploring the Djado Basin, Niger, for oil. The exploration is at an early stage, the first exploratory hole being drilled at the time of my visit. The work in this basin is fairly typical of the French technique of oil exploration.

The Djado Basin contains little folded sediments from Cambrian to Carboniferous in age, unconformably overlain by Cretaceous and a veneer of Tertiary sediments. The older units crop out around the margins of the basin. Carboniferous sediments crop out within the basin and outline minor structure in many places.

The first phase of exploration consisted of photogeological mapping of the basin. This was followed by one season of reconnaissance mapping, consisting mainly of stratigraphic studies, section measuring and sampling and some formation boundary mapping. The results of this work are used to re-interpret the initial photogeology and a modified photogeological map was produced. This map, at a scale of 1:500,000 covered the entire basin. More detailed photogeological maps at a scale of 1:100,000 were prepared covering the entire basin area.

The second phase of exploration consisted in part of intensive stratigraphic studies in the good outcrop areas around the margins of the basin. This includes mainly detailed section measuring and sampling. In this work, the detailed stratigraphy is determined as far as possible, and sedimentary structures and facies are studied. The other parts of the second phase involve use of both geological and geophysical techniques to outline structure within the basin. Some of the structures within the basin were outlined on the photogeological maps. These are mapped in great detail by a geologist and surveyor team, to determine the existence of closure on the structure. Regional gravity and magnetometer surveys have been run over parts of the basin. Seismic surveys have been made in some areas and are continuing. Reflections are generally poor though one shallow horizon is giving good reflections which can be traced over big areas. At the time of my visit, the company were considering using "thumper" seismic.

Detailed stratigraphic mapping was continuing at the time of my visit. The results of this were revealing defects in the 1:500,000 map of the basin. However, the company did not consider it necessary to revise the map. Their detailed work is plotted mainly as vertical columns and cross-sections and is available for direct comparison with the results of drilling.

The first exploratory well was drilled late in 1961. It had reached 1800 metres by mid-December, in partly silicified sandstone and orthoquartzite of Cambro-Ordovician age. I examined the Schlumberger logs run and the cuttings and some cores from this hole, studied the duties of the well-site geologist and some of the technical aspects of drilling.

The calci-log was run at this well. Washed and dried cuttings are quartered down to give a representative sample of about 10-20 gms. weight. This is ground to a powder, of which about 0.5 gm. are weighed accurately and placed in a small flask. A tube of dilute hydrochloric acid is placed in the flask, which is then connected to an alcohol manometer. The flask is tilted to spill the acid which attacks the powdered sample. After 3 minutes the increase in pressure due to carbon dioxide production is measured. This gives an estimate of the calcium carbonate content. The flask is then heated to allow the acid to attack any dolomite in the sample. The pressure is measured after allowing the entire system to cool back to room temperature. Any increase in pressure is related to the total carbonate content. The pressure readings are corrected for temperature and pressure. The percentages of calcium carbonate and total carbonate in the sample are calculated from a set of graphs.

Iranian Oil Exploration & Producing Company

Exploitation Geology Department

DUTIES OF RESIDENT GEOLOGISTS

Masjid-i-Sulaiman
August, 1961.

EXPLOITATION GEOLOGY DEPARTMENT

TECHNICAL INSTRUCTION

DUTIES OF RESIDENT GEOLOGISTS

1. GENERAL REMARKS

The duties of a Resident Geologist have been dealt with piecemeal in Administrative Instructions issued by Headquarters from time to time over the past three years. They are succinctly summarised in the formal Job Descriptions.

The purpose of this Instruction is to assemble the material from all previous documents on the subject in one comprehensive compilation.

2. APPROVED ESTABLISHMENTS

Three-well Field

Resident Geologist	1
Resident Geologist (Supernumerary)	1
Geologist II, or III	1
Junior Geologist	1
Ustad-Kar	1
Slidemakers	9

Two-well Field

Resident Geologist	1
Geologist II, or III	1
Junior Geologist	1
Ustad-Kar	1
Slidemakers	7

One-well Field

Resident Geologist	1
Geologist II, or III, or Junior Geologist	1
Slidemakers	4

Exploration Well

Resident Geologist	1
Geologist II, or III	1
Ustad-Kar	1
Slidemakers	4

Contd.

Workover Project

Geologist II, or III (as required)	1
Slidemakers (as required)	3

3. PRIMARY RESPONSIBILITY

3.1 General

The primary and paramount responsibility of the Resident Geologist is the maintenance of absolute geological control over all wells in the area assigned to him. This control is maintained only by adherence to a general pattern of operations, carried out with scrupulous care, which has proved over a period of years to be successful if not allowed to deteriorate into a blind habit. This means that at all times the Resident Geologist must cultivate and combine a critical approach to technical problems with a sceptical attitude of mind to unproved hypotheses, however plausible these may be.

3.2 Well Control

3.2.1 Sampling interval

In general, assuming adequate quality and quantity of samples, control can usually be maintained by using the following sampling intervals:-

Bakhtiari) Upper Fars)	10 feet
Middle Fars (Marl Member)	5 feet
Middle Fars (Limestone Member)) Lower Fars, Member 7)	2 feet
Lower Fars, Members 6 - 2 :-	
Salt and Marl Sections	5 feet
Anhyd. and Lst. Sections	2 feet
Lower Fars, Member 1 (Cap Rock)	1 foot
Asmari and Pre-Asmari	2 feet

These are not rigid limits. In areas of structural uncertainty, Members 6 to 2 should be scrutinised with care. This will frequently necessitate closer sampling, circulating samples from bottom or even coring.

Contd.

Where, for reasons of weak circulation, presence of lost circulation material, inappropriate mud properties or similar adventitious factors, the samples become poor in quality and/or quantity, the Resident Geologist must exercise extreme care. In such cases, key-beds and characteristic stratal assemblages may be missed unless energetic measures are taken to obtain representative material from the hole. These include coring, insertion of sample-collecting devices in the fluming, requests for improvement of circulation and/or mud properties and the like. These steps will require the cooperation of other Departments and, if justified, will always receive the support of H.Q.

3.2.2. Sample Segregation on Site

The responsibility for segregating and collecting samples of cuttings from the mud in circulation at the requested intervals lies with the driller on shift; but the actual task is usually delegated to the labourer whose duty is to keep the mud-screen free of obstructions.

Occasional unobtrusive checks are necessary to guard against two major but unavoidable risks in this arrangement:- (a) forgetfulness on the part of the screen labourer whereby, having omitted to collect a sample from the screen before clearing it, he may take a grab-sample from the accumulated pile of perhaps the last 30 feet of samples; and (b) forgetfulness on the part of the driller, whereby no samples are taken at all over one or more intervals.

In making these checks, care must be taken not to forfeit the goodwill of the drillers and labourers. This goodwill must always be guarded and fostered. The checks are, however, obviously desirable from time to time and are, for example, absolutely necessary where an apparently monotonous series of samples of the same rock-type cannot be correlated with a variable drilling-rate, or where widely diversified rock-types appear over an interval in which the drilling-rate is constant.

When lost-circulation material is in circulation, various devices such as fluming-baffles, trap-doors or by-passes must be tried out, in order to obtain adequate and reliable samples. The Drilling Department should be asked to cooperate in advising on and designing such items.

It is generally desirable that samples should not be washed on site. Over-vigorous washing may eliminate characteristic marls and, when cuttings are small, may entail much loss of harder rocks; while there is danger that salty samples may be ruined by washing in fresh-water.

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3.2.3. Sample-Collection from Site

The responsibility for the collection of batches of samples from the drilling-site lies with the Resident Geologist. The frequency of such collections must obviously be keyed to the drilling rate, the stratigraphic position at current bottom, and the urgency with which information is required.

As far down as, say, 100 feet above the base of Lower Fars, Member 7, samples may be collected at most twice a day, merely to keep up with the drilling-rate, unless a casing point depends on a formation boundary or key-bed.

Below the base of Lower Fars, Member 7, drilling rates are normally so high and key-beds are of such importance, particularly in regions of poor structural control, that a greater frequency of collection is desirable. As far as possible the timing of collections made more than twice a day should divide the whole 24-hours into approximately equal intervals, except as modified by periods when no drilling is taking place.

In critical situations, such as those of loss of control or of approaching or suspected Cap Rock, it is desirable that the Resident Geologist, equipped with adequate labour, slide-making materials and a microscope, should stay on site until the immediate problem is resolved.

Samples must be collected initially so that they are in the laboratory, washed and ready for inspection by the Resident Geologist at starting time every morning (7 days per week).

This implies work outside office-hours for both staff and labour. It is therefore appropriate to emphasise at this point that the work of the Resident Geologist and his personnel is regulated not by official working hours but by the current stratigraphic situation in the wells under his control. Sometimes, it may be possible to synchronise the work with office hours - but this will be an exceptional coincidence, which must not under any circumstances be forced at the expense of safe well-control.

3.2.4. Laboratory Procedures

3.2.4.1. Sample Preparation

On arrival at the laboratory, the samples should be carefully washed and sieved under the supervision of the foreman, a small part of the unwashed sample being retained for separate scrutiny.

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Occasional inspection of the process by the Geologist III is desirable to check (i) that soft samples are not disintegrated by vigorous treatment; (ii) that sieves suitable for the average cuttings-sizes are employed; (iii) that samples from saliferous formations are being washed in concentrated brine; (iv) that adequate precautions are taken to avoid switching of samples or interchange of samples from two or more wells.

3.2.4.2. Examination of Cuttings

The examination and recording of constitution in percentages may, at the discretion of the Resident Geologist, be delegated to other staff members, but the adequate description of these samples remains the responsibility of the Resident Geologist. If this task is delegated by the Resident Geologist, he must, nonetheless, carry out a preliminary general inspection of the cuttings, so that important key-beds are not missed, misidentified or underlogged.

Provided the material does not disintegrate in water, samples are examined wet, colours being assessed by comparison with the standard "Rock-Color Chart" issued by the Geological Society of America (1951). The use of a binocular microscope is advantageous and desirable to aid in the proper assessment of rock type and other pertinent features. It is essential in Asmari and pre-Asmari material. Basic rock types are described and classified in accordance with the "Note on terminology of the description of sedimentary rocks adapted for use in Iran" (S.E. Watson, 1961).

Potential reservoir rocks, whether carbonate or clastic, are described and classified according to the Archie system. This system enables a quantitative evaluation of porosity and permeability to be carried out by visual examination of the cuttings.

When drilling rates are high, it is necessary for the Resident Geologist, in his cursory inspection, to earmark immediately for slide-preparation any samples likely to yield features of diagnostic value, such as rare limestone fragments in a marl series or of anhydrite in a salty sequence. This prevents loss of time in gaining important evidence which would otherwise only come to light in the routine serial slide-preparation.

The inspection for recording the percentage constitution is normally combined with the careful serial selection of material for slide-preparation. The type of cuttings so selected must, for greatest value, be related to the stratigraphic position. Thus, in Upper Fars, rare stringers of anhydrite are not relevant, whereas similar stringers in the salty Lower Fars may be of

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paramount importance as key-beds. The picking of cuttings for slides must never be allowed to degenerate into a blind non-selective routine.

3.2.4.3. Slide Preparation

The grinding of cuttings and the preparation of microscope slides is left entirely to the laboratory labour under the supervision of the foreman, subject to general supervision by staff. Stringent precautions are necessary to avoid any possibility of the transposition of samples from any one well or the interchange of samples from two or more wells.

3.2.4.4. Examination of Slides

In the examination of microscope slides, the following data should be recorded:-

(a) Rock types
(b) Lithology and texture
(c) Mineralogy and habit
(d) Fissures and fractures
(e) Evidence of hydrocarbons
(f) Fauna

The emphasis to be placed on these points depends on the stratigraphic context, and is a matter of individual discretion; but, in every case, every available piece of information must be recorded on the form provided specifically for this purpose. (Form No. 73.611(7-61)).

It is, of course, assumed that the Resident Geologist has been trained in basic stratigraphical palaeontology. It is his duty to apply his knowledge to the configuration of Iranian facies and faunas, and to familiarise himself with at least the key microfauna of the general succession, with particular emphasis on the Asmari and pre-Asmari. To assist him, numerous general and special references are available in the Geological Library and the Geological Report Files respectively, and the Palaeontological Section is always ready to advise. However, all Resident Geologists must be prepared to make routine determinations of significant forms that will enable them to define all important time-horizons at least as far down the succession as the base of the Albian.

Certain of the microscopic slide examinations are, inevitably, delegated to other Geological staff members; but, as with the cuttings

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examination, the Resident Geologist should make a rapid inspection of beds which appear significant. The ultimate responsibility for the correct assessment of the geological position remains squarely with the Resident Geologist.

As a general rule, with periodic checks, Junior Geologists rapidly attain competence to control wells as far down as the base of Lower Fars, Member 7; while, with close supervision, Geologist III's may be allowed some responsibility below this horizon. This generality must, however, be modified to meet the idiosyncrasies of individual fields as well as variable levels of skill and training of the individuals concerned.

In all cases, wherever the merest suspicion of the proximity or presence of Cap Rock arises, the Resident Geologist must personally carry out the examination of all cuttings and slides.

3.2.5. Coring Procedures

3.2.5.1. General Remarks

The occasional necessity of coring for geological information has already been noted. Similar coring for reservoir engineering data is also carried out. In each case, the Resident Geologist has certain obligations.

3.2.5.2. Requests for Coring

Coring for geological information is generally requested when inadequate samples threaten a loss of stratigraphic control or when confirmation of Cap Rock is required. Poor sample quality most usually results from bad hole conditions (shows, losses, caving), and thus coring often becomes desirable under the most difficult mechanical conditions

Compliance with such requests is naturally reluctant and it is a matter of routine cooperation to seek other means of regaining control beforehand. When these fail or are impracticable, however, there must be no hesitation about requesting at least spot-coring to be carried out until control is regained. In such cases, the request must be pressed with tact and firmness, and Geological H.Q. should be advised of the situation by telephone. If still opposed, the request should be repeated in writing; the letter should be addressed to the Drilling Superintendent, copied to District Superintendent (Basic), Chief Drilling Superintendent and to Geological H.Q. giving a concise account of the reasons for the request, the quantity and/or periodicity of coring required, and a brief comment on the consequences of continued loss of control beyond the point at which the request was made.

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3.2.5.3. Collection of Cores

It is the responsibility of the Resident Geologist to be present when the core is lifted from the hole and extracted from the core-barrel and to collect and label the core in properly designed core-boxes. Where the core has been specifically requested by the Petroleum Engineering Department, these responsibilities are jointly shared with the representative of that Department, if present.

In the latter case, selected portions of the core are usually placed in special cans on site for onward despatch. In any event, the whole or part of the core remaining is taken to the Geological Laboratory for examination.

3.2.5.3. Notes on Core Phenomena

Observations made on a core depend upon the purpose for which the core was taken. Of these, there are four main geological categories, viz.

(a) Key-Bed Identification

The majority of cores taken to identify key-beds are from the incompetent Lower Fars when sample quality has seriously deteriorated. Attention should be concentrated on, and specimens for microscopic examination taken from, all beds or stringers of indurated marl, limestone and anhydrite. Dips are not significant except perhaps if there is consistency of dip throughout the core.

(b) Cap Rock Identification

In regions of poor structural control, it is frequently possible for the actual position of the Cap Rock to be 1000 feet or more different from forecast. Where such uncertainty is combined with poor or unreliable samples, it becomes necessary to core all anhydrite beds which persist for 5 feet, once the drill has penetrated within what the Resident Geologist may consider at the time to be the zone of uncertainty.

Often, several such cores are necessary; but this should not be the occasion for a gradual relaxation of vigilance. In fact, of course, the chances of the core being Cap Rock increase with depth, and each successive hard layer should be regarded as potential Cap Rock until proved not to be so.

Each core should be inspected on site, as soon as extracted. A succession, including such anhydrite as was drilled before coring, of 6 to

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15 feet of anhydrite followed by up to 3 feet of brown bituminous marl is, in both Agha Jari and Gachsaran, a strong pointer to Cap Rock.

Subsequent discovery, under the microscope, of Carbonate D in the anhydrite is highly indicative; but Cap Rock should not be officially confirmed before the appearance of the Upper Cap Rock Limestone, as it is possible, particularly in Gachsaran, for Carbonate D and bituminous marl to be brought tectonically in close juxtaposition within the higher members of the Lower Fars.

(c) Cap Rock Confirmation

It occasionally happens that samples are sufficiently ambiguous or contaminated to render it advisable to core after Carbonate D has been identified. This is particularly the case where marl cavings are present and a mud treated with quebracho is in circulation. Both of these events combine to simulate or mask the presence of bituminous marl, thus introducing the risk of over - or under-logging the bituminous marl.

Where this opportunity has been missed but there is still presumptive evidence of Cap Rock, a forecast from available data of the position of the Cap Rock Limestone must be made and a core taken over the most probable interval. (In Agha Jari, for example, a 20-foot core commenced 40 feet below the presumed top of Cap Rock will intersect the Cap Rock Limestone if the dips lie between 20° and 50°. In most wells to be drilled, a somewhat closer estimate of dip is possible).

(d) Reservoir Stratigraphy and Structure

Occasionally, the coring of the reservoir formation (Asmari or pre-Asmari) becomes a joint project with Petroleum Engineering Department to obtain stratigraphic and physical data. This allows an excellent opportunity for obtaining detailed information with the greatest economy of effort. The more fossiliferous layers can be selected for slide-preparation without the necessity, as in cuttings-samples, of preparing slides non-selectively at every interval. Moreover, continuous coring provides a statistical dip-record normally of greater validity than the Schlumberger dip-meter survey, which does not always distinguish between bedding and well-developed joint systems.

All perinent data concerning the core and the description of the core are recorded on the core report form. (Form No. 73-68 (rev. 7-61))

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4. SECONDARY RESPONSIBILITIES

4.1 General Remarks

Besides the primary responsibility of well-control, the Resident Geologist is responsible for the assimilation, correlation, synthesis, and dissemination of all available geological information pertinent to the area to which he is assigned. That such tasks increase his efficiency in well-control is an obvious and important by-product of the undertaking; satisfactory advice on geological matters can never be given unless the question at issue in all aspects, together with all possible solutions, is clear in the mind of the adviser.

4.2 Areal Geology

An early task of the Resident Geologist is that of familiarising himself, by all means available but chiefly by physical exertion, with all the details of the surface geology of his area, with its relationship with that of contiguous neighbourhoods, and with its position in the whole tectonic and stratigraphic complex which makes up the Agreement Area.

This will involve, when time allows, the examination and measurements of sections, the running of instrumental cross-sections, revisional mapping, visits to neighbouring areas and copious reading. It normally forms, therefore, a long-term project which may not be completed during the time of assignment.

However, familiarisation of this sort frequently forms an incidental part of other geological tasks, as will be described in subjacent paragraphs.

4.3 Sub-Surface Geology

The Resident Geologist must not only familiarise himself with the influence of the surface structures on the reservoir dome and with the configuration of the dome itself; he must continually assimilate and continuously review the current interpretation of the reservoir structure in the light of new data and deductions therefrom. This involves critical study of information on dips and of observations on stratigraphy and lithology, and the preparation and revision of exhaustive correlation charts and cross-sections. Above all, his attitude to the current interpretation, even where based on comprehensive dada and close control, must be one of scepticism, tempered with surprise only in the event of the interpretation proving correct. Phenomena demonstrating the unreliability of many widely-held and time-hallowed hypotheses are not uncommon occurrences.

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4.4. Well Location

An important function of the Resident Geologist is the accurate physical location of sites for drilling wells.

4.4.1. Development Wells

The steps in the procedure for the location of a normal development well on an established field are:-

(a) The schematic location, sited solely in relation to the most up-to-date U.G.C. map available, is one of a group recommended to Mangement by Petroleum Engineering Department, and approved after discussion between the Management and the Pertinent Departments. (C.D.S., C.P.E. and C.E.G.), The schematic location is, at the outset, usually given as a general area some 1/4 mile wide along and up to 1 mile long across the contours, to allow for subsequent structural revisions.

(b) As and when it is decided to drill on a particular schematic location, the Resident Geologist inspects the general vicinity, if necessary runs an instrumental section to fix precisely the surface structure, assembles all possible up-to-date information bearing on the local configuration of the reservoir, and selects a suitable structural location for a well to reach the reservoir on the desired contour. He then revisits the site and identifies the exact spot of the structural location. Should it appear to him suitable for rig-erection, he immediately cairns the spot. If, as is more likely, it is not suitable, he moves the location along the desired contour to the nearest suitable place for rig erection and cairns the selected place.

(c) When this procedure is completed, the Resident Geologist informs Geological H.Q. of the proposed location, supplying documentary and other supporting data for his selection.

(d) As soon as possible, the site is visited by Senior Exploitation Geologist in company with the Resident Geologist. The duty of the former is to check the location, alter it if necessary, and indicate clearly the extreme limits within which it may subsequently be moved for mechanical reasons.

(e) The Resident Geologist then convenes an offical Drilling Location Party, consisting essentially of the Drilling Superintendent, the Area Construction Engineer, and other parties in the area who are directly concerned with the location preparation. This party visits the location and

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examines its mechanical aspects in detail. Should their final choice of location lie within the bounds prescribed, a final cairn is built and marked, surveyed in by a surveyor supplied by or designated by Geological H. Q., then or at an early date, the original cairn destroyed, and all concerned are advised.

(f) Should the Drilling Location Party wish to move the site beyond the prescribed limits, particularly athwart the contours, a cairn may be built, but will not be ratified and approved until revisited by Senior Exploitation Geologist, who will approve, or record reasons for not approving, the location.

(g) In the event of disapproval by Senior Exploitation Geologist, the further steps to be taken depend on discussion between those concerned with the Headquarters and, if necessary, with Management. Under these circumstances, the final location will be approved directly by Management, advised by appropriate H. Q. staff.

(h) In areas of little or no topographic relief where it is difficult to ascertain ground positions by means of a compass, a surveyor supplied by or designated by Geological, H. Q. will be made available to fix the initial location position on the ground (e. g. areas such as Khalafabad and Ahwaz).

4. 4. 2. Exploration Wells

Exploration wells for geological purposes may be defined as major geographic or stratigraphic outsteps from developed areas. The location procedure is closely similar to that of development wells. However, since the formal location takes place as much as a year before spudding in, a Resident Geologist is not usually involved.

4. 5. Advisory Duties

The Resident Geologist's obligations to other Departments are strictly advisory. This advisory function is of two kinds. On the one hand, he must always be in a position to reply reliably and comprehensively to all questions seeking information of a geological nature concerning his area. On the other hand, he may, at his own discretion, volunteer advice on geological matters affecting areal operations.

Usually, this advice deals with such items as recommendations on casing programs where these are based on the stratigraphic succession, forecasts of mechanically troublesome horizons and suggestions for coping

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with them and the like; but it must be remembered that the status of the Resident Geologist in this respect is that of an adviser only. He may suggest or advise certain actions for the improvement of operational procedures beyond his direct control but may never request or insist on them. By placing such advice on written record, he fulfils his obligations to those to whom the advice is offered.

5. OFFICE PROCEDURES

5.1. Recording of information

All pertinent information which comes to light during the drilling of a well should be permanently recorded. This information is recorded either in routine reports or special notes and is filed accordingly, thus forming part of the permanent Geological Records. The following regular reports are required:-

5.1.1. Daily Geological Report: This report is made out daily for each well active in the field or area on a standard form which enables most of the basic information required for the report to be filled in as the cuttings samples are examined. The Daily Geological Report Form comprises sections for recording sample descriptions in percentages, comments on the samples themselves, comments on drilling activities during the preceding 24 hours, a synopsis of mud properties, and information concerning fluid losses and/or shows of any type. A copy of the Daily Geological Report is sent to Headquarters for scrutiny and filing and one copy goes into the appropriate well file in the Resident Geologist's office. Locally, copies should be made available for scrutiny (but not retention unless a specific request is made) by the District Superintendent (Basic), Resident Petroleum Engineer, and Drilling Superintendent. Resident Geologists on outside exploration wells should send two copies of the Daily Geological Report to Headquarters, the extra copy being for despatch to Tehran. The Daily Geological Report should be typewritten on the appropriate form. (Form No. 73.607 or 73.610).

5.1.2. Slide Descriptions

The thin sections are examined and descriptions are made on forms provided for this purpose. The descriptions are made in duplicate and one copy is sent to Headquarters for scrutiny and filing while one copy is retained for the appropriate file in the Resident Geologist's office. (Form No. 73.611 (7-61)).

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5.1.3. Weekly Geological Report

This report is prepared only by Resident Geologists on outside exploration wells. It is a concise, factual statement of activities, geological and mechanical, which took place on the well during the previous week. Two copies of this report are sent to Headquarters, who in turn forward one copy to Tehran. (Note: in some instances this report may not be required).

5.1.4. Monthly Report

The Monthly Report is primarily a technical report summarising the geological activities of the preceding month and should always follow the basic rules of report presentation. It is prepared by Resident Geologists on both exploitation and exploration wells, and should include a general well summary in tabular form, followed by reports on individual wells and general information. The reports on individual wells contain sections on drilling activities, testing, mud, shows and losses, stratigraphy, structure, and Schlumberger logs. Detailed and lengthy statements on mud and drilling activities are not necessary. Stratigraphy and structure should receive comprehensive treatment. It must, however, be borne in mind that this is primarily an objective report of events; all deductions, inferences and intuitive inspirations based on these events must be clearly differentiated from the facts in a separate section. Looking through the field copies of previous Monthly Reports is helpful as they give in indication of the format and type of content which is desirable. Columns accompanying reports are frequently of value in demonstrating the stratigraphic relationship of a particular well to surrounding wells.

The Monthly Report should be completed as soon as possible after the first of the month. Six copies of this report are required in Headquarters, of which four copies are sent to Tehran. The local distribution would normally be one copy each to District Superintendent (Basic), Resident Petroleum Engineer, and Drilling Superintendent, these copies being for retention or perusal at the discretion of the Field Administration. Generally speaking only the R.P.E. actually needs a copy for retention.

5.1.5. Annual Report

This report is prepared by all Resident Geologists, whether in developing fields or on outside exploration wells. The Annual Report should be a concise factual statement of geological activities in the area

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concerned during the course of the calendar year. As much data as possible should be presented in tabular and statistical form. The geological highlights of the preceding year should be briefly discussed Changes in staff throughout the year as well as numerical changes in labour strength should be listed. Previous Annual Reports should be consulted for guidance on format, etc. The Annual Report should be submitted to Headquarters as soon as possible after the first of the calendar year. Distribution and copies required are the same as for the monthly report.

5.1.6. Graphic Logs

Graphic Logs are kept on all wells drilled. The following logs are required:-

Surface to total depth	scale 1:1000
Cap Rock	scale 1:200
Asmari and pre-Asmari	scale 1:200

At present logs are made up on transparent forms provided for this purpose. Two coloured copies of all logs are required for Headquarters, one for retention here and one copy for Tehran. In practice the transparent logs are sent to Headquarters for printing and the prints are returned to the field for colouring. Standard colours are used, a list of which is available in each Resident Geologist's office. The Graphic Logs are a means of presenting in concise form all pertinent geological and mechanical data on a well, and provide space for the recording of information on penetration rate, bit changes, casing strings, lithologic data, Schlumberger logging, cores, drilling fluid properties, shows of various types, etc. In active fields, a great deal of time is taken up with log plotting and it is sometimes necessary to let the logs wait while slides and samples are worked up. This is acceptable provided a rough copy of a graphic log is kept up-to-date for correlative purposes. However, efforts should be made to supply finished portions of the graphic log to Headquarters as quickly as possible.

5.1.7. Completion Reports

A Completion Report is written on each well after active operations on it are terminated. It is a concise factual summary of events occurring during the drilling of the well and the results obtained from the well. Completion Reports are prepared on a standardised format, a copy of which is available in Resident Geologist's offices. The Completion Reports for exploration wells differ from those of exploitation wells only in the

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relative length of some sections of the report, e.g. stratigraphy, and the number of illustrations appended to the report. Existing Completion Reports in the files should be consulted to obtain an idea of format and contents. Normal distribution for a Completion Report is three copies for Headquarters and five copies for Tehran. Local distribution is at the discretion of the Resident Geologist.

5.1.8. Formation Forecast and Geological Recommendations

This important document is prepared by the Resident Geologist when a drilling location for a well has been finally selected. It contains all pertinent geological information required for the preparation of the drilling program. This document follows a standard format (see available examples). It is submitted in draft form to Geological Headquarters where any revisions or modifications deemed necessary are made directly on the draft. One copy (annotated) is returned to the field and the other copy is filed in Geological H.Q. The Resident Geologist then produces, for distribution, the finalised copy of the formation forecast and geological recommendations. Sections touching upon things not strictly geological (such as casing, mud, testing) should be prepared after discussions with the Resident Petroleum Engineer and Drilling Superintendent. Any amendments to the finalized document require the same procedure before issuing.

5.1.9. Drilling Programs

Present practice requires that drilling programs be drawn up by the Resident Petroleum Engineer, but that such programs incorporate, after due consideration, the formation forecast and geological recommendations issued by the Resident Geologist. The drilling program is signed by the Resident Geologist and the Resident Petroleum Engineer and then submitted to H.Q. for final approval. Any departures from the geological recommendations should be pointed out to H.Q. Geological as well as to the Resident Petroleum Engineer as soon as noticed in the draft copy of the drilling program.

5.2. Office Routine

The order of priority of work in the Geological Office should be as follows:-

1. Examination and description of cuttings samples and selection of slide material.

2. Examination and description of slides.

3. Preparation of daily reports of a routine nature such as the daily geological report.

4. Keeping graphic logs up-to-date.

5. Other projects, assignments, etc.

It is recognized and understood in Headquarters that there are times when the Resident Geologist must single out a particular task or well as being especially critical. When this happens the other tasks may fall momentarily behind. However, every effort should be made to keep up-to-date on all routine work.

5.3. Non-Routine Reports

Additionally the following reports are required to Headquarters, Geological Department:-

5.3.1. Daily Phone Call. The Resident Geologist should contact the Senior Exploitation Geologist, or in his absence the Head of the Department, by telephone or radio, by 10.00 a.m. or sooner every morning (7 days per week). The purpose of this call is to report the stratigraphic horizon of the well plus any other pertinent data. Sample quality, penetration rate, and any correlations with adjacent wells fall into the category of pertinent data.

5.3.2. Other Phone Calls. Any key-bed, whether provisional or confirmed, should be reported to Senior Exploitation Geologist or, in his absence, to the Head of the Exploitation Geology Department as soon as possible. Likewise, all beds of interest (e.g. hard drilling in an anhydrite which could be suspected as Cap Rock) should be immediately reported whether officially classed as a key-bed or not.

5.3.3. Technical Notes: The Resident Geologist is expected to become an authority on the geology of his assigned area. Accordingly, he will prepare, as time permits, various notes and diagrams (sections, maps, etc.) which will add to the sum total of geological knowledge of his assigned area. This will involve doing limited amounts of field work in order to provide the basic data for structural sections, dip surveys etc. A technical note may be written on any aspect of the geology of the area which,

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in the opinion of the Resident Geologist, needs exposition. As part of his duties in an assigned area, a Resident Geologist may from time to time be requested by the Field Administration to provide opinions on aspects of geology unrelated to drilling wells, e.g. building stone, water supply, foundations, etc. Any opinions or information of this type delivered by the Resident Geologist form part of the ever-growing mass of geological data on the area.

5.4. Geological Files: A filing system exists in the Department which is largely self-explanatory. A master list of all files in use in the Department is available in each office together with an explanation of its basic principles. Strict adherence to this filing system is necessary if we are to prevent a chaotic dispersal of information. Misfiled information is, to all intents and purposes, lost.

6. REPORTING RELATIONSHIPS

6.1. Senior Exploitation Geologist

The Resident Geologist reports directly to the Senior Exploitation Geologist and through him to the Head of the Exploitation Geology Department. This necessitates the maintenance of close contact with H.Q. Geological at all times.

6.2. District Superintendent (Basic)

Within his assigned area the Resident Geologist, works within the Administrative framework supervised by the District Superintendent (Basic) or, in the case of Resident Geologists on Exploration Wells, of the Project Manager. The Resident Geologist is an integral part of the local field personnel and carries out in good faith all administrative matters concerning his section in accordance with instructions and policy promulgated by the District Superintendent (Basic). Any apparent conflicts between the administrative sphere and the technical side of the work should be reported to Geological H.Q. immediately. Under no circumstances can we accept at field level procedures which in any way negate, dilute, or otherwise impinge upon the technical standards and technical effectiveness required of this Department, even though such infringements by the local administration may be inadvertent.

6.3 Operational Liaison

Additionally, within his assigned area the Resident Geologist maintains close working relationships with the Drilling Superintendent, Resident Petroleum Engineer, and all other personnel with whom his duties bring him

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into frequent daily contact. In general, these relationships are amicable and are founded upon mutual respect for each section's technical problems and the abilities of the people involved in solving these problems. The overall goal of these technical sections must be the same, i.e. the efficient safe exploration and drilling for, and production of, oil. Although pleasant and amicable working relationships with other sections are highly desirable (this should be obvious and the reasons therefore need no elaboration), they must never be brought about by a relaxation of the working and technical standards of our Department, even though our maintenance of these standards may cause discomfiture of others.

6.4. Miscellaneous

Whenever possible, any queries or points of difference that arise on the local scene should be settled locally insofar as this is consistent with Departmental policy, while keeping Geological H.Q. informed at all times of the issues and progress involved. Should an issue become intractable locally, Geological H.Q. stands ready to aid in its solution by vigorously seeking a ruling, from Management if necessary, at the Headquarters level. However, to provide the backing necessary for instances which may arise, we require complete possession of all facts pertinent to the problem. These can only be supplied by the Resident Geologist.

D. L. Little

Senior Exploitation Geologist

L. E. T. Parker

Head, Exploitation Geology Department

Masjid-i-Sulaiman
15th August, 1961.
DGL/is

BMR Record 1962/112

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GEOPHYSICAL ENGINEERING
SEISMIC - GRAVITY - MAGNETIC
CABLE ADDRESS
"ROBRAY" BENGHAZI

CONSULTING

Benghazi Office
P. O. Box 220

PLAYBACK PROCEDURE:

Each channel on the raw field tape represents six drops. In the first analyzer operation the raw field tapes are photographed and a new tape is made, called the "D" tape; the photograph is referred to as a "Single". The "D" tape and the "Single" photograph contain identical information. Each trace represents, depending upon the drop pattern, that number of drops that will give twenty traces;e.g. if the drop pattern is 12 drop tangent circles, each channel on the "D" tape represents two field tape channels or twelve drops. In this case twelve drops is equivalent to one circle. In the event the drop pattern is 24 drop tangent circles each channel on the raw field tape represents six drops, or one circle is composed of four tracks and forty tracks are required for one spread of 24 drop tangent circles and two "D" tapes of 20 tracks each are required for one spread.

The "C" tape is made from the "D" tape. All corrections for elevation and normal moveout are applied in this step. A variable density, variable area, galvo trace section or combinations of the galvo trace and variable density or area sections are made from this tape. Any of the various composites can be applied. The usual composite in Libya is 2/1. This figure indicates that each trace on the final section represents two "C" tape channels, one of which is mixed with the adjacent trace. The 2/1 composite is roughly the equivalent of a 50% geophone overlap used in conventional seismic work. Each section represents eight spreads.

The normal moveout is removed by a cam cut to a prescribed velocity usually obtained from a continuous velocity log recorded in a deep well.

B

Enclosure No. 1:

Enclosure No. 1 is a print of four photographic records illustrating some laboratory signal and noise tests which require a little explanation. These tests offer excellent proof of the noise cancelling ability of the Geograph integration procedures.

On Record "A", the first trace, labeled "Signal", was made by recording the unfiltered output of a single geophone held in the hand and tapped at intervals. The second trace and the first 24 traces of Record "B" are the output of a geophone on the hood of a truck with the motor running in an attempt to create random noise. These first 24 traces of Record "B" were recorded on 24 separate rotations of the drum to stimulate random noise that would be recorded on 24 separate drops. The noise records have a broad spectrum of frequencies which certainly appear (within reasonable limits) to include the spectrum of frequencies generally encountered in random noise on seismic records.

The third trace (signal plus noise) of Record "A" is a simple compositing of the first two traces. All traces of Records "A", "B", and "C" are unfiltered. This third trace illustrates how the signal is buried in or obscured by the noise when the signal-to-noise ratio is about one to one.

The bottom trace of Record "B" is an example of what random noise will do to cancel itself by phase discrimination, by paralleling the 24 noise traces into one trace. In photographing this bottom trace of Record "B", the gain and level of the amplifier were left the same as in the 24 traces above; therefore, the reduction in noise level on this last trace is an actual reduction, accomplished by phase discrimination of the random noise.

On Record "C", the signal trace of Record "A" was added to each of the first 24 traces of Record "B". If these 24 traces are studied individually, it will be seen that in general, the signal-to-noise ratio is of the order of one to one. These 24 traces were then paralleled into the one resulting trace at the bottom of Record "C". Notice the obvious large increase in signal-to-noise ratio, accomplished without the use of filtering.

Record "D" illustrates the 24 traces of Record "C" when filtered through an SIE GA-11 amplifier 1-20-64. The bottom trace of Record "C" is a composite of the above filtered 24 traces of Record "D" photographed at the same recording level as the individual traces. The bottom trace illustrates the cancelling effect phase discrimination has on filtered records.

Enclosure No. 2:

Enclosure No. 2 illustrates with actual field recordings what can be accomplished by use of various degrees of compositing and filtering in an area of extraneous and horizontal disturbances. The flexibility of the analyzer allows the use of only that amount of integration necessary to raise the signal-to-noise ratio to the desired level.

The top four records, Nos. 1 thru 4, inclusive, are single drops made by dropping in a straight line from 1,000 feet away from the patch, through the patch to 1,000 feet on the other side. The drops are 21 feet apart and are "in-line"; that is, the drops were made in a straight line along the line of profile rather than in a more complicated zig-zag or circular pattern. The fact that the drops are reproduced here unfiltered accounts for the extreme amount of wind noises, 120 cycle pickup, air wave, and other stray noises displayed on the individual traces.

The first composited record (No. 5) is the result of integrating four adjacent drops into one trace, filtering the data and correcting it for weathering, elevation, and drop time. In this example, normal moveout was not removed. In other words, this record is made by compositing the first four singles to form the first trace, the second four singles to form the second trace, and so on until all the singles of the top four records are combined to form the first composited record. There is no mix or carryover of any kind on this record. Note how much of theundesired noises shown on the single drop traces have been eliminated with composite of only four drops per trace.

An analogy which is often used to aid in comparing weight dropping procedures to conventional seismic reflection methods is to consider weight dropping as the reverse of conventional recording. Therefore, in the example outlined above, it may be considered that the weight was dropped at each spot where a single geophone would be placed in conventional shooting and that the combining of four drops into one trace is analogous to conventional recording with four geophones per trace. At the point where the shot point (or pattern of shot holes) would be placed in conventional shooting, a "patch" of geophones is placed. The number of geophones per patch may vary from 24 to 288 (or more), depending upon the difficulty of obtaining useable reflections. The distance between "patches" varies from approximately 1,000 feet to 4,000 feet or even longer in some instances in which it is desirable to accomplish velocity profiling.

The next record (No. 6) shows a composite of eight single drops per trace with four drops carryover from one trace to the next. This means the record has some ground mix in that each adjacent trace has four drops that are common to both traces.

The next record (No. 7) shows a higher degree of compositing in that each trace is the composite of 12 single drops and adjacent traces have eight drops that are common to both.

The last record (No. 8) shows a high degree of compositing in that each trace is the composite of 20 single drops and adjacent traces have 16 drops that are common to both.

You will note that the higher the compositing used, the higher the signal-to-noise ratio. Of course, there is a limit to the degree of compositing that one can use and the last record of 20 over 16 is as high as we recommend. Even with this high degree of mix, the "step-out" of events for this last record is the same as those of lesser composites.

Enclosure No. 3:

Enclosure No. 3 shows the comparison of weight dropping energy to dynamite in a picked area of the Delaware Basin where the horizontal reverberations are a minimum. The three records were made by conventional 24-trace magnetic recording equipment. There were 10 geophones per trace, and the level and sensitivity of the recording equipment was the same for all three records. The bottom record is the recording from a pattern shot in which 10 holes were drilled 39 feet deep, spaced 60 feet apart and loaded with 10 pounds of power in each hole giving 100 pounds for the pattern. The middle record is the recording from a single hole, 200 feet deep, and loaded with 50 pounds of powder. The top record is the recording from a single drop of the weight beside the deep 200-foot hole.

It is indeed amazing that the single drop of the weight gives as good or better record than the dynamite when one considers that the dropping of a 6,000 pound weight nine feet is equivalent in total power to only one-half ounce of 60 percent gelatine dynamite. This is proof that the weight drop is many times as efficient as dynamite in setting up an elastic wave. Of course, in areas where the horizontal reverberations are high, it is necessary to drop the weight many times in different places in order to minimize this horizontal energy by cancellation.

Enclosure No. 4:

Enclosure No. 4 is a sample of Geograph records taken in North Africa over sand dunes that were approximately 100 feet high. These records were made from saw-tooth pattern dropping with 12 drops per segment and composites four over three; that is, four segments of 12 drops each were composited to form the first trace and three segments of 12 drops each were composited with an additional segment of 12 drops to form the next trace, and so on. The patches were 400 meters apart, and 288 geophones were used in each patch.

Enclosure No. 5:

Enclosure No. 5 illustrates a general comparison of Geograph and conventional seismic records recorded in Libya. The comparison is not a direct one in that the two lines are 1.3 kilometers apart and the conventional records have been heavily marked before the photograph was made. The two lines are parallel with the top of each section being the north end of the line. The spread length is 400 meters in both instances.

The Geograph records were obtained from dropping a saw-tooth pattern with 12 drops per segment. The Geograph patches contained 288 geophones each and were 400 meters apart. These records were filtered 1-20-1-42 through an SIE GA-11 amplifier.

The conventional records were obtained from pattern shooting. The shot hole pattern consisted of 18 holes in a hexagonal pattern, the holes being 20 feet deep with 10 pounds of 60 percent explosive in each hole. The geophones were laid out in a split spread of 24 traces with 24 geophones per trace. The conventional records were filtered 1-24-1-60 through an SIE GA-22A amplifier.

Enclosure No. 6:

Enclosure No. 6 is a sample of Geograph records taken in Val Verde Basin of West Texas. These are made from circle pattern dropping. The circles were 400 feet in diameter and were overlapping 50 percent; each circle was composed of 72 drops. The patches contained 288 geophones each and were spaced 2,000 feet apart. The composite is 1/0, which means that each trace is the composite of the 72 drops for that circle. There are no drops from one trace used in another trace. Note the steep dip portrayed by the Devonian reflections.

Enclosure No. 7:

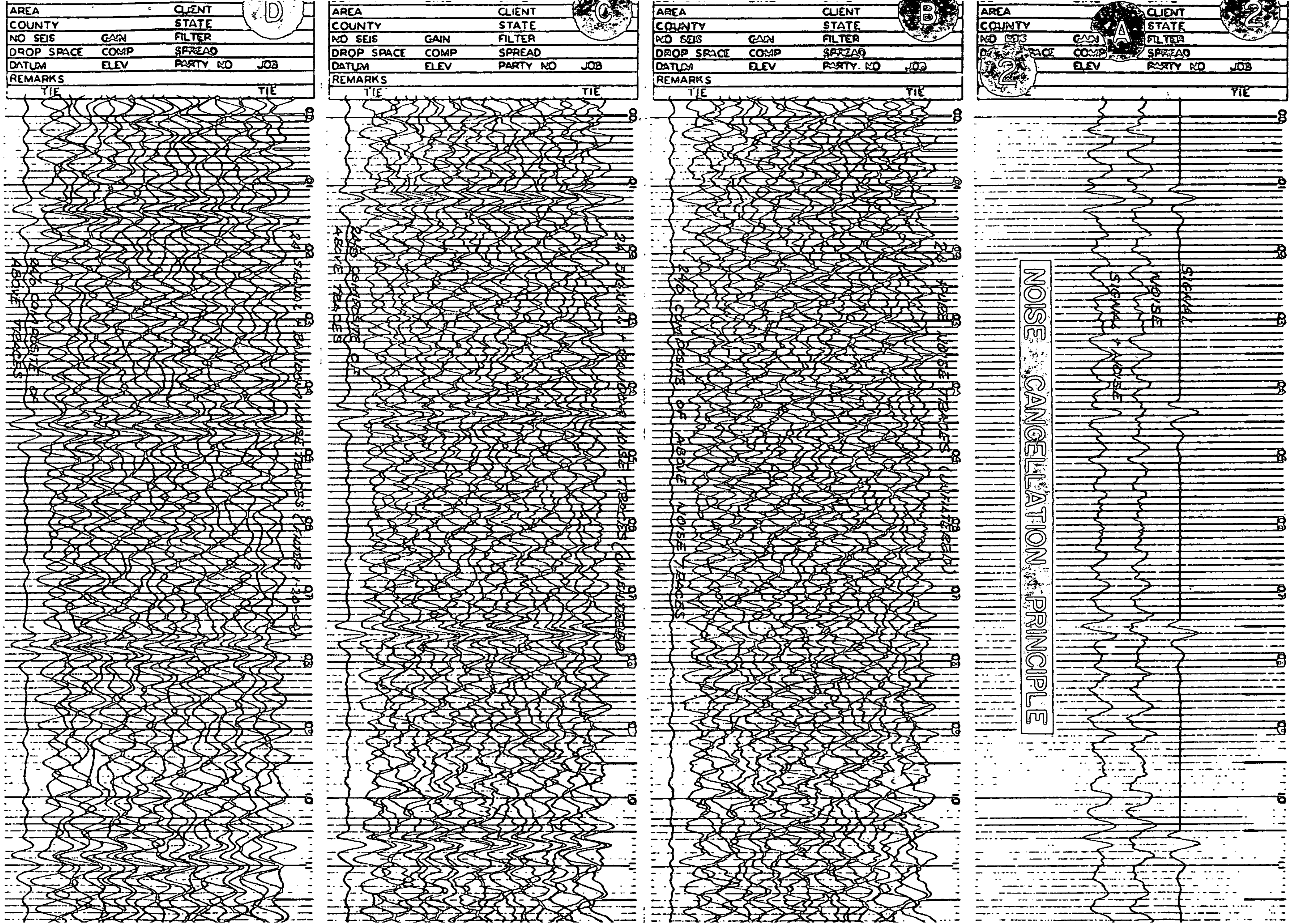
Enclosure No. 7 is another example of Geograph record from the Val Verde Basin of West Texas. This is also 1/0 with the same technique as Enclosure No. 6; however, this record shows faulting in the Devonian section with very good character.

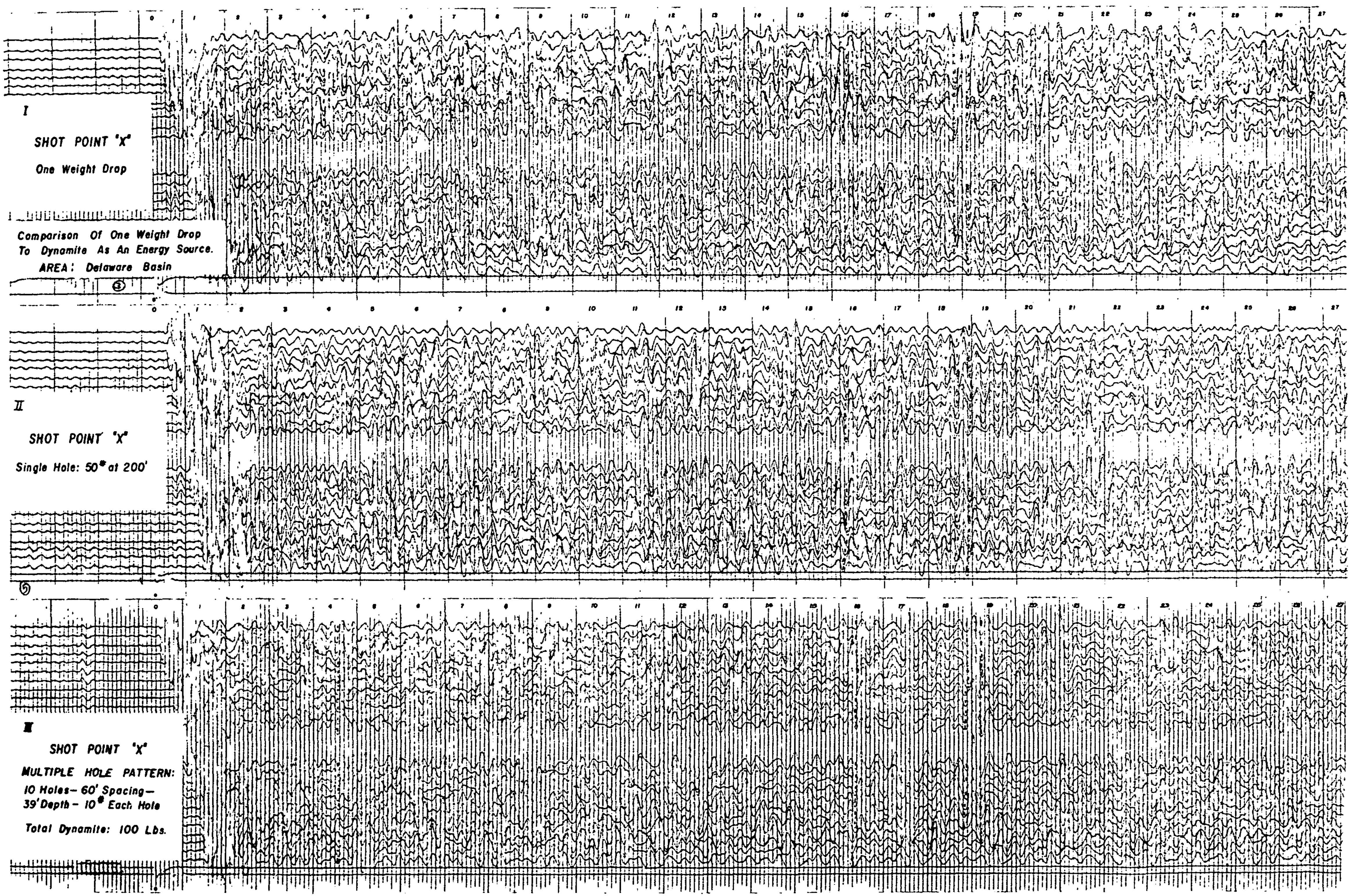
Enclosure No. 8:

Enclosure No. 8 is the same as Enclosure No. 7, except that the composite is 4/3 which means that the first trace is the composite of four circles after "step-out" corrections have been made between circles and then three of these circles are carried over to the second trace. This is a high degree of ground mix, but the same faults are shown as in Enclosure No. 7, and the signal-to-noise has been greatly increased. Also, one can see that this additional compositing has brought out another reflecting event between 1.2 and 1.5 seconds that was very difficult to see in Enclosure No. 7, which was a 1/0 composite.

Enclosure No. 9:

Enclosure No. 9 is a sample of Geograph records taken in Libya, North Africa. This is zig-zag dropping, with six drops to the segment. The patches had 288 geophones in each and were spaced 500 meters apart. The composite is 2/1 or two segments of six drops each were composited to make the first trace and one segment of six drops was carried over to the second trace. This is some ground mix, but not very high, and the record shows numerous reflecting horizons. With this method, the Geograph crews in Libya have averaged over five kilometers per day for more than six months working seven days a week. The cost per kilometer of Geograph operations in Libya for this work is approximately one-half to one-fourth that of conventional equipment in the same area.


AREA
CLIENT
COUNTY
STATE
NO SEIS
GAIN
FILTER
DROP SPACE
COMP
SPREAD
DATUM
ELEV
PARTY NO
JOB
REMARKS
TIE
TIE
D
C
B
A
2
NOISE CANCELLATION PRINCIPLE
SIGNAL
NOISE
SIGNAL + NOISE


I
SHOT POINT 'X'
One Weight Drop
Comparison Of One Weight Drop
To Dynamite As An Energy Source.
AREA: Delaware Basin
II
SHOT POINT 'X'
Single Hole: 50# at 200'
III
SHOT POINT 'X'
MULTIPLE HOLE PATTERN:
10 Holes- 60' Spacing-
39' Depth- 10# Each Hole
Total Dynamite: 100 Lbs.

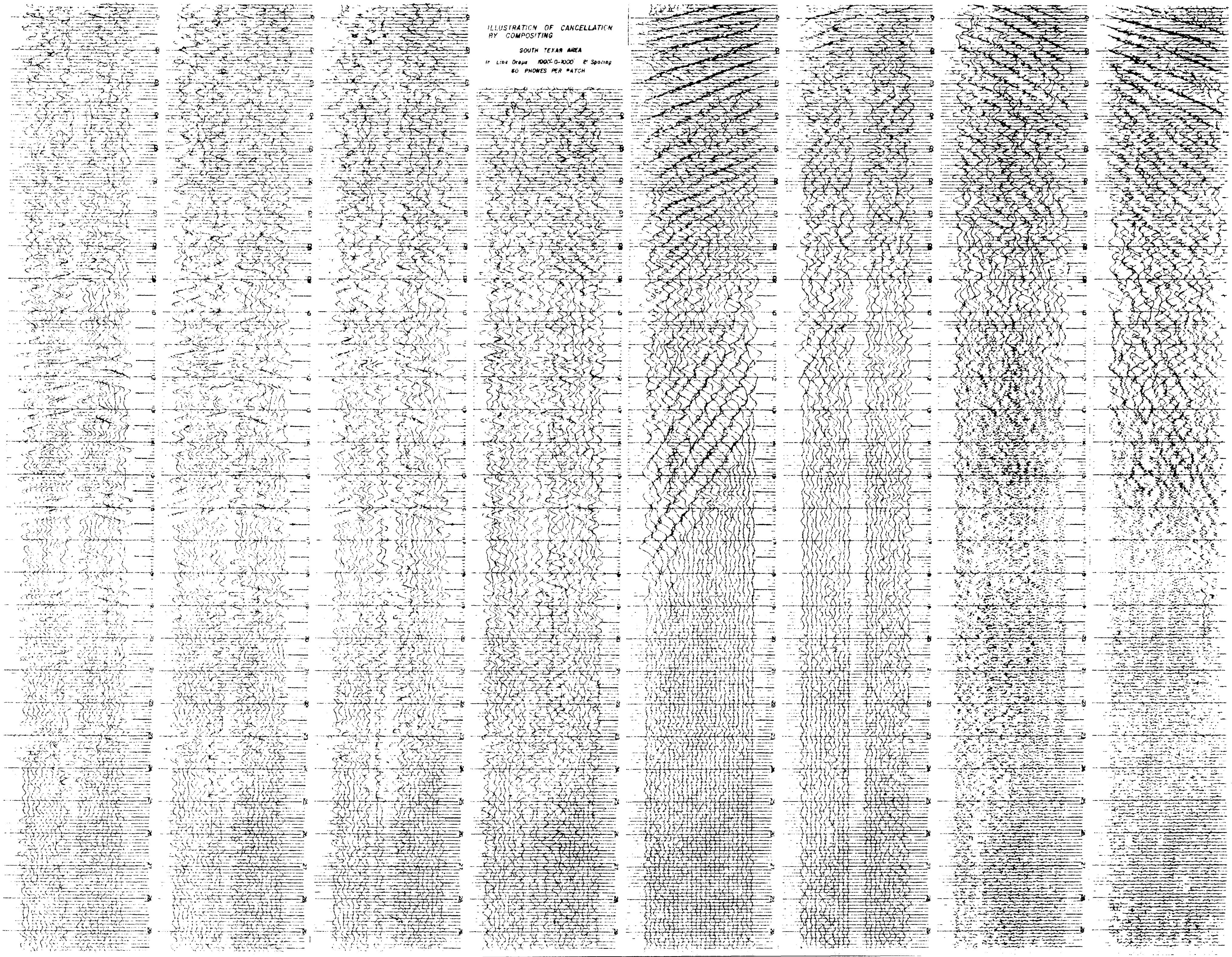


ILLUSTRATION OF CANCELLATION BY COMPOSITING

SOUTH TEXAS AREA

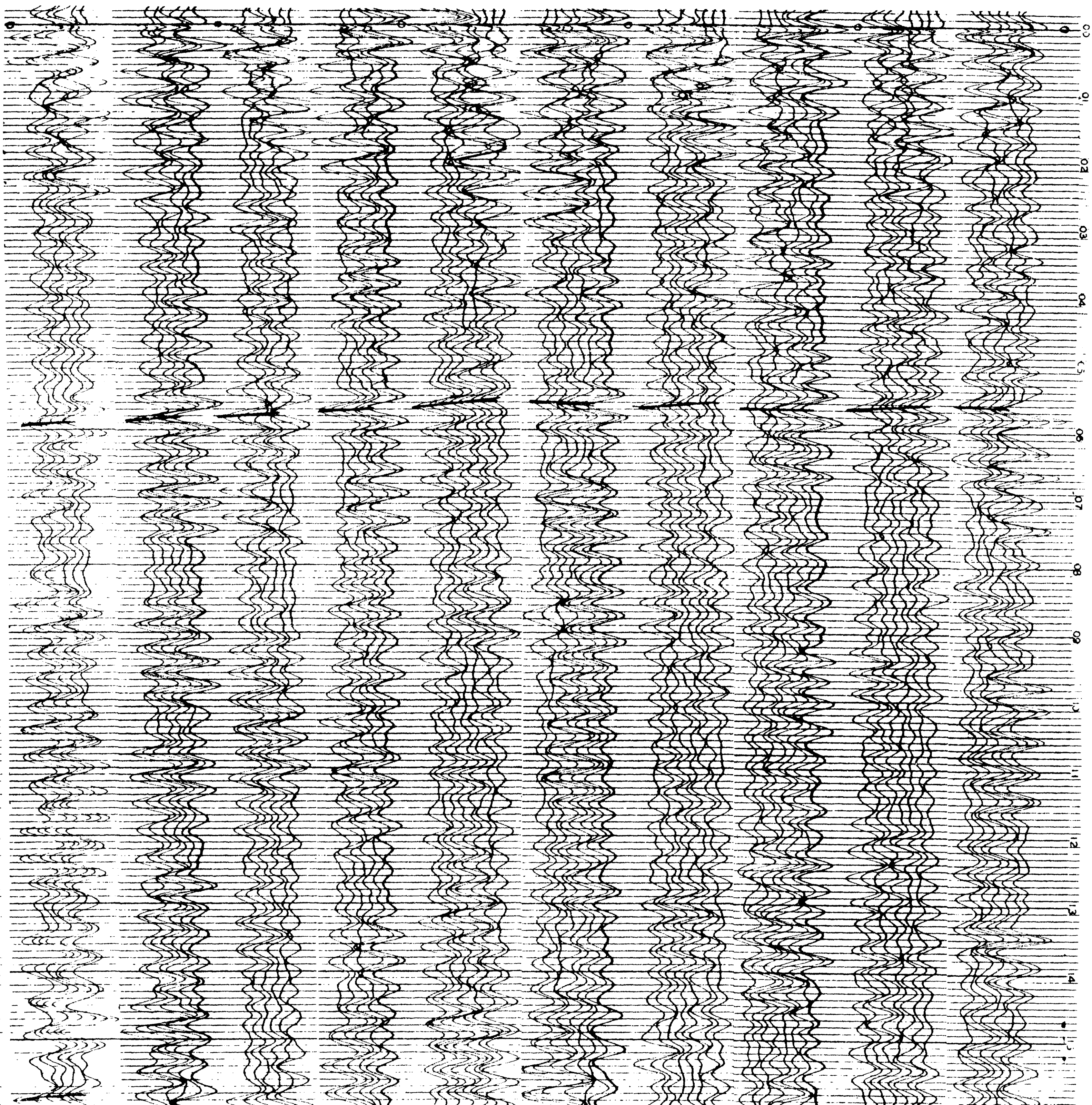
Ir Line Drops 1000'-0-1000' 8' Spacing

60 PHONES PER PATCH

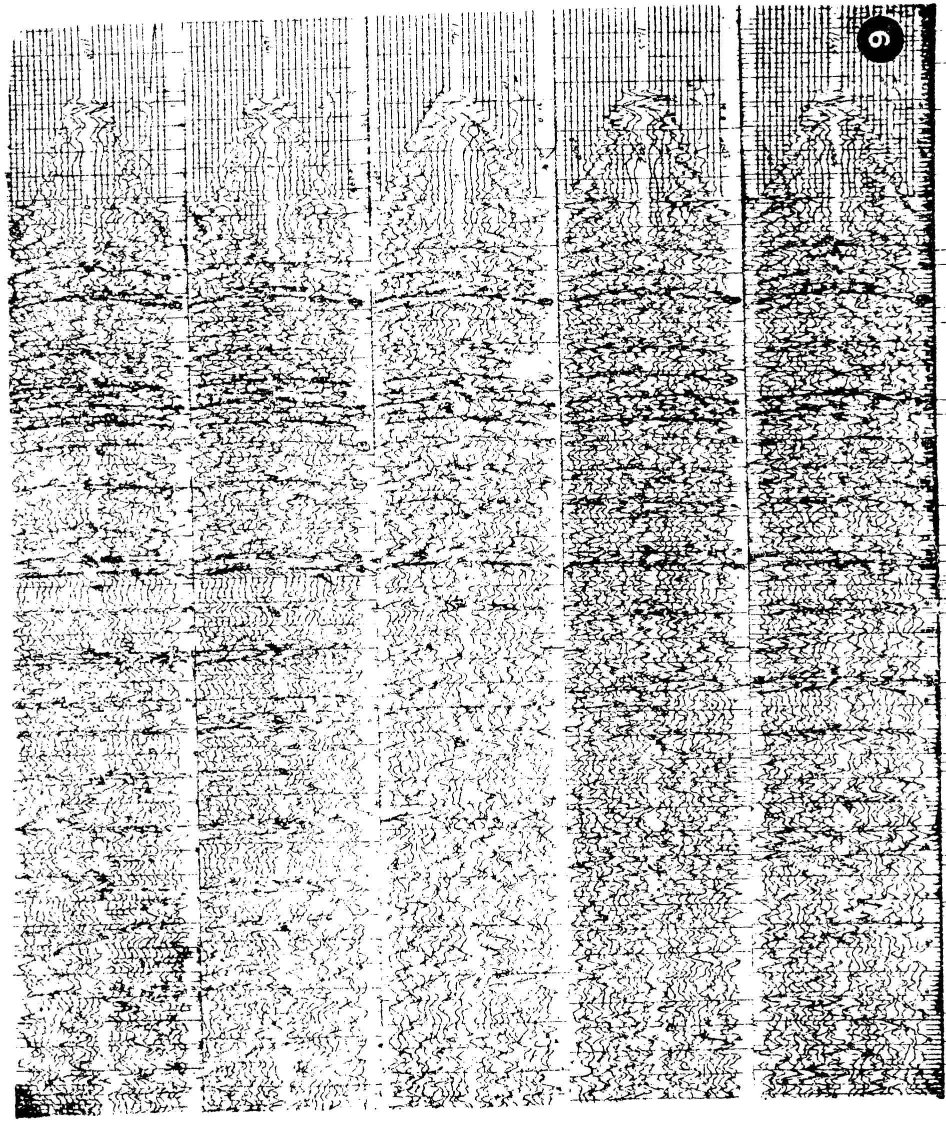
McCollum Ray International, Inc.

Geograph Sand Dune Records – Libya – Sawtooth Pattern – 12 Drops Per Segment

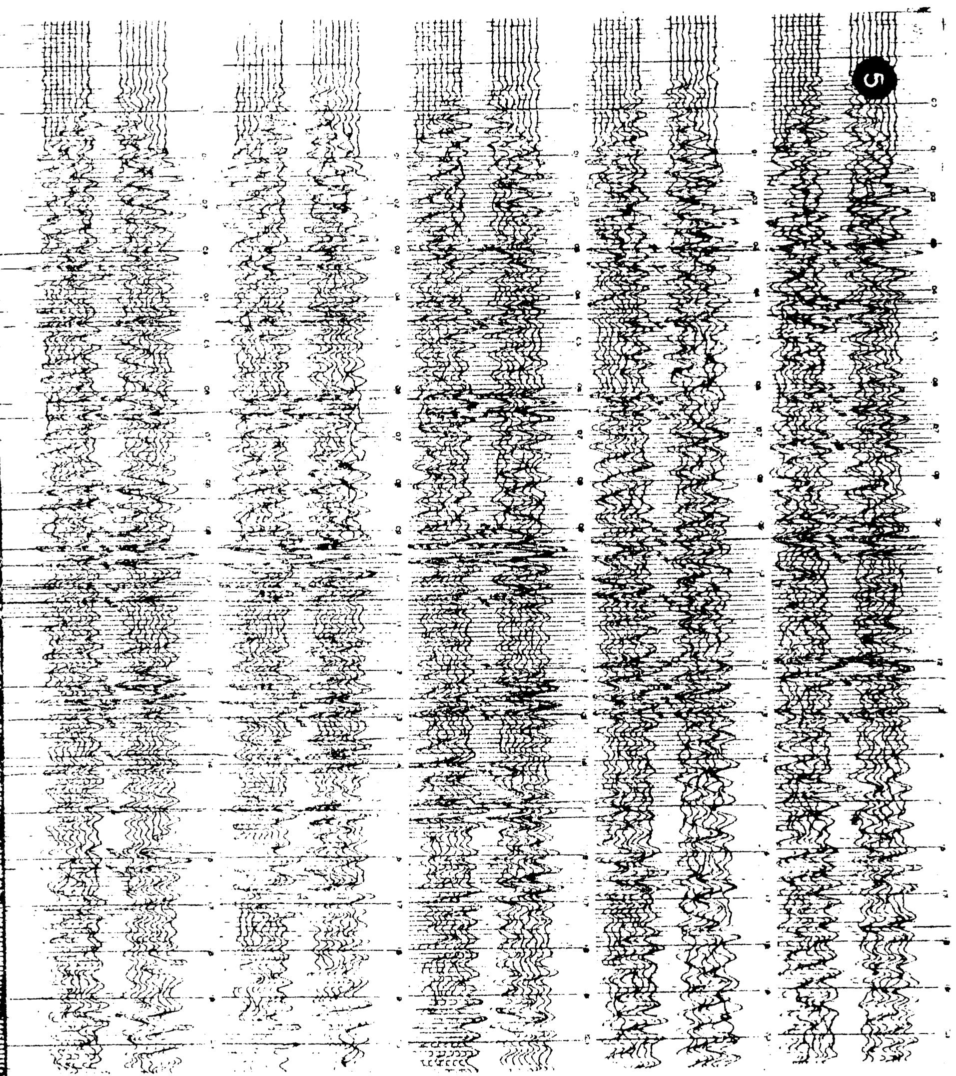
4/3 Composite – 400 Meter Spreads – Sand Dunes Approximately 100 Feet High



Pattern Hole Record From Libya
18 Hole Pattern - 10 Lbs. Per Hole - 20' Deep
24 Phones Per Trace - 400 Meter Spreads

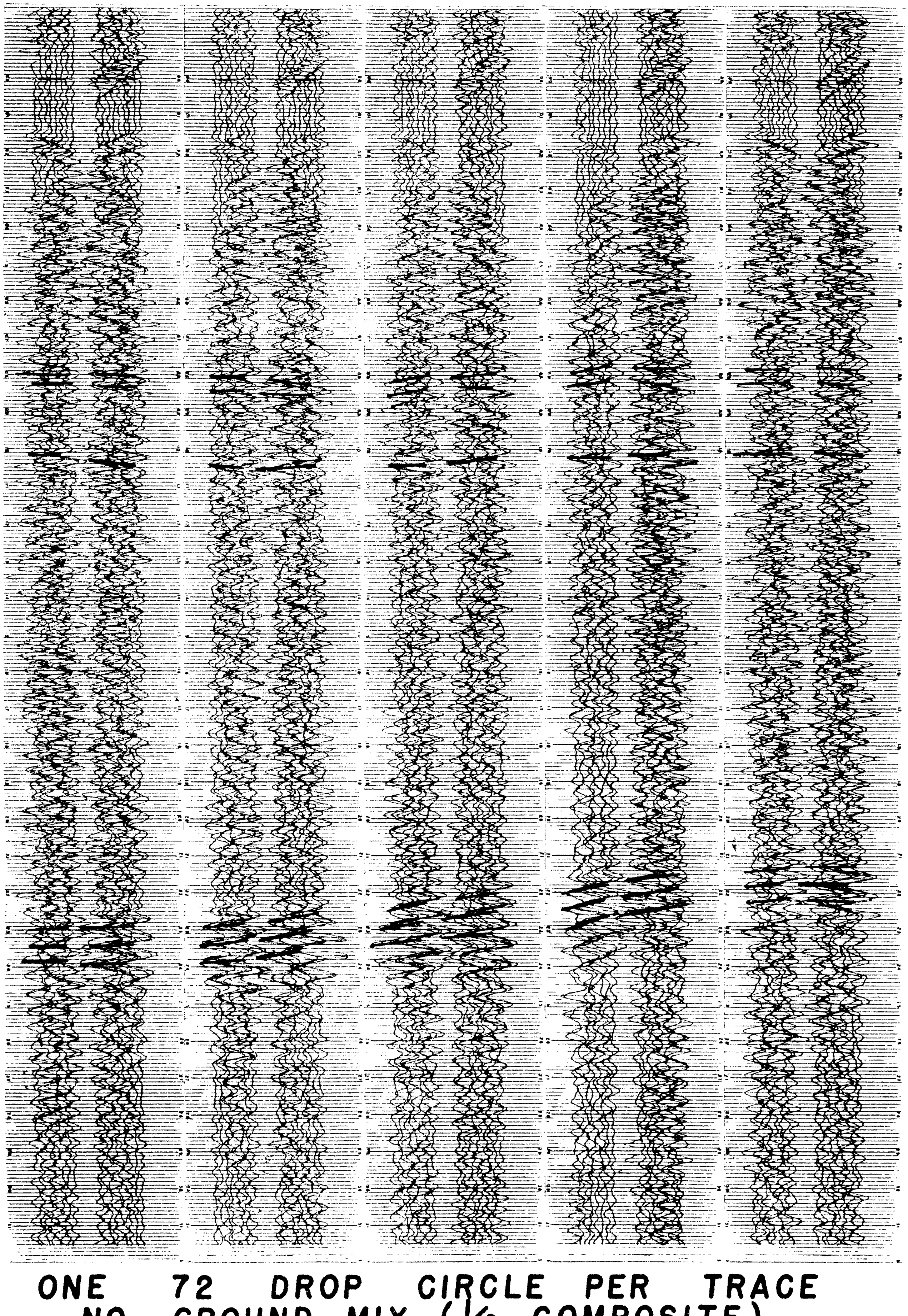


Geograph Record From Libya
Sawtooth Pattern - 12 Drops Per Segment
288 Phones Per Patch - 400 Meter Spacing
No Ground Overlap



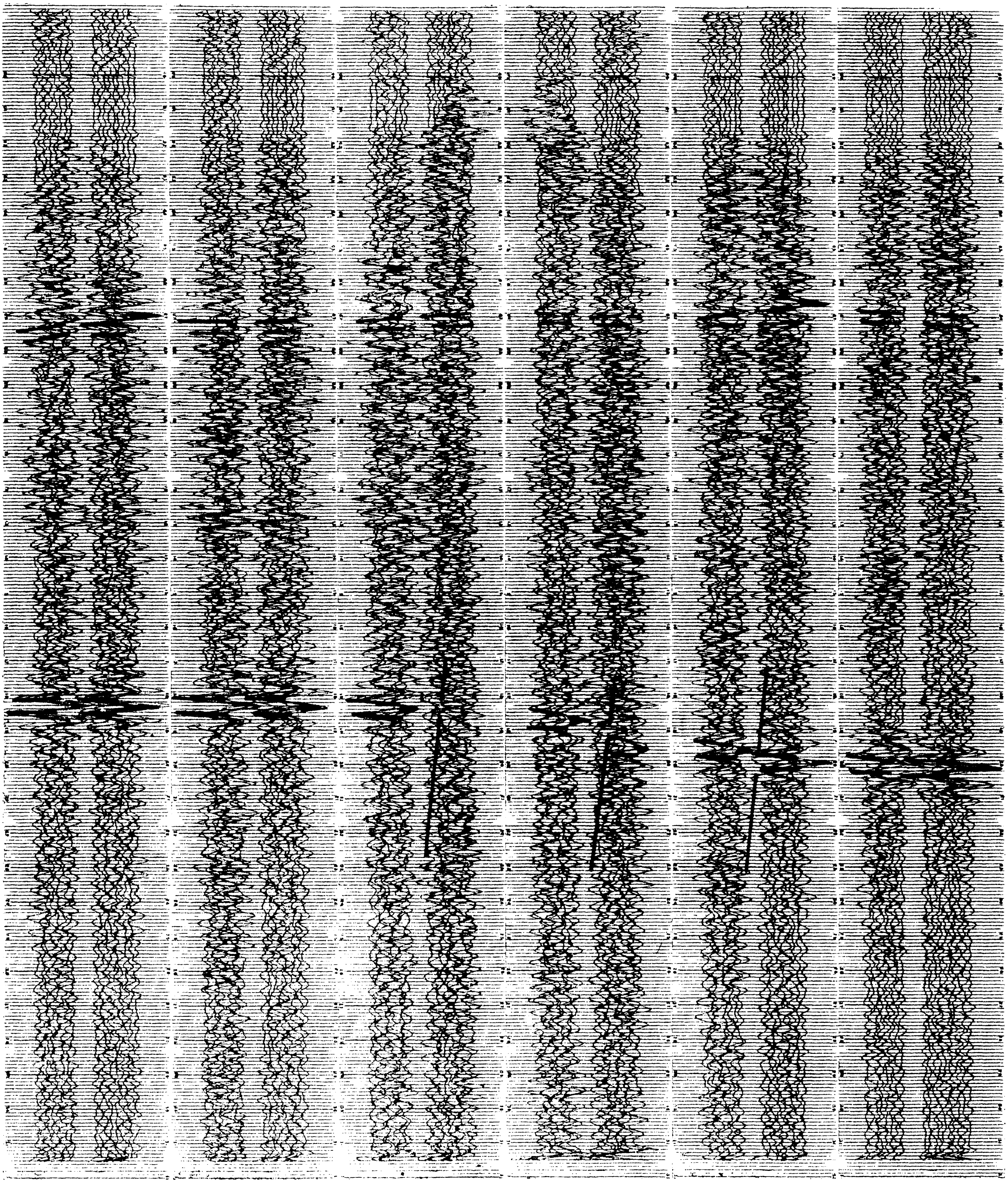
ROBERT H. RAY COMPANY, INC.

GEOGRAPH RECORDS — VAL VERDE BASIN, TEX.



ONE 72 DROP CIRCLE PER TRACE
NO GROUND MIX (1/0 COMPOSITE)
288 GEOPHONES PER PATCH

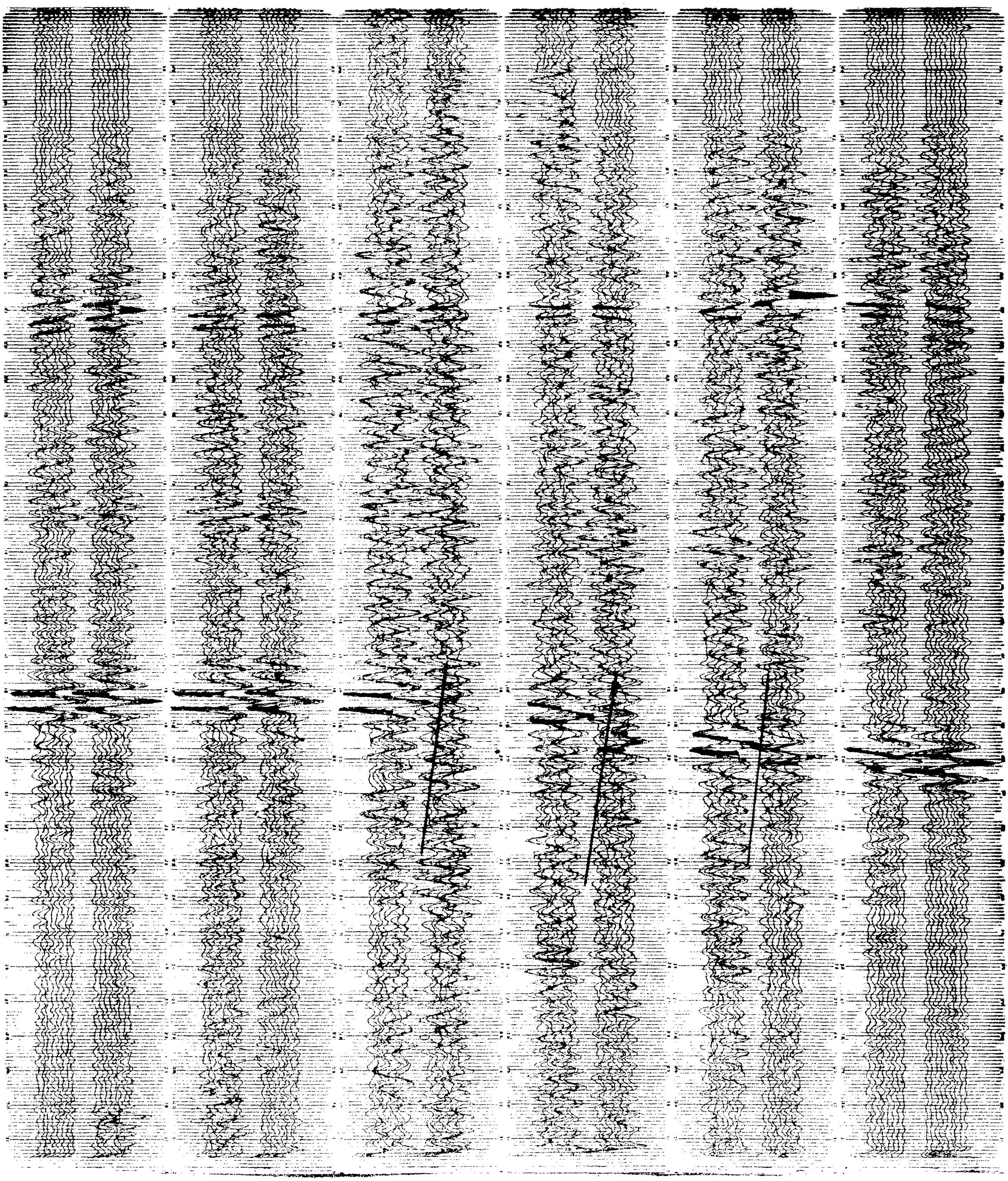
ROBERT H. RAY COMPANY, INC.
GEOGRAPH RECORDS — VAL VERDE BASIN, TEX.



ONE 72 DROP CIRCLE PER TRACE
NO GROUND MIX (1/0 COMPOSITE)
288 GEOPHONES PER PATCH

ROBERT H. RAY COMPANY, INC.

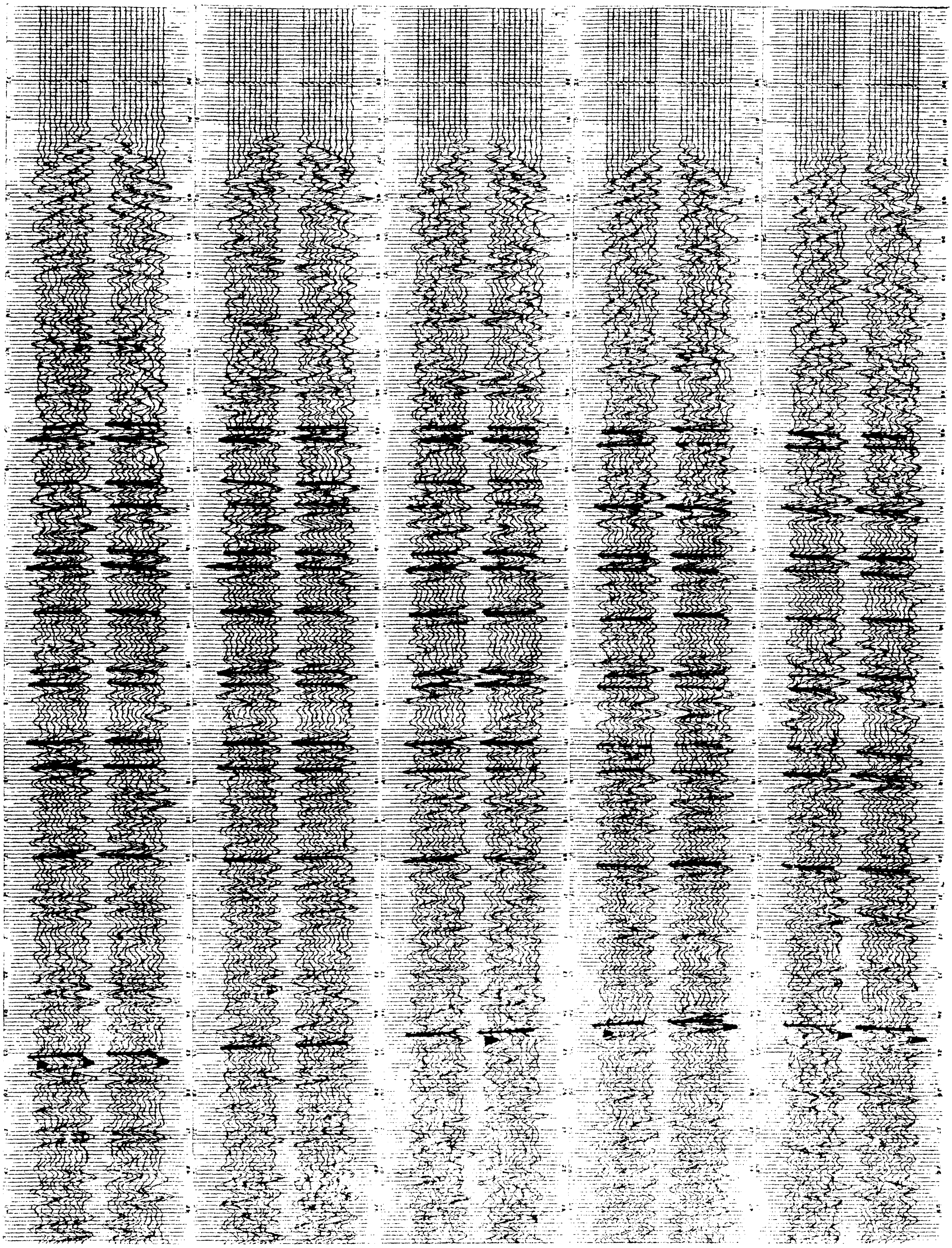
GEOGRAPH RECORDS VAL VERDE BASIN, TEX.



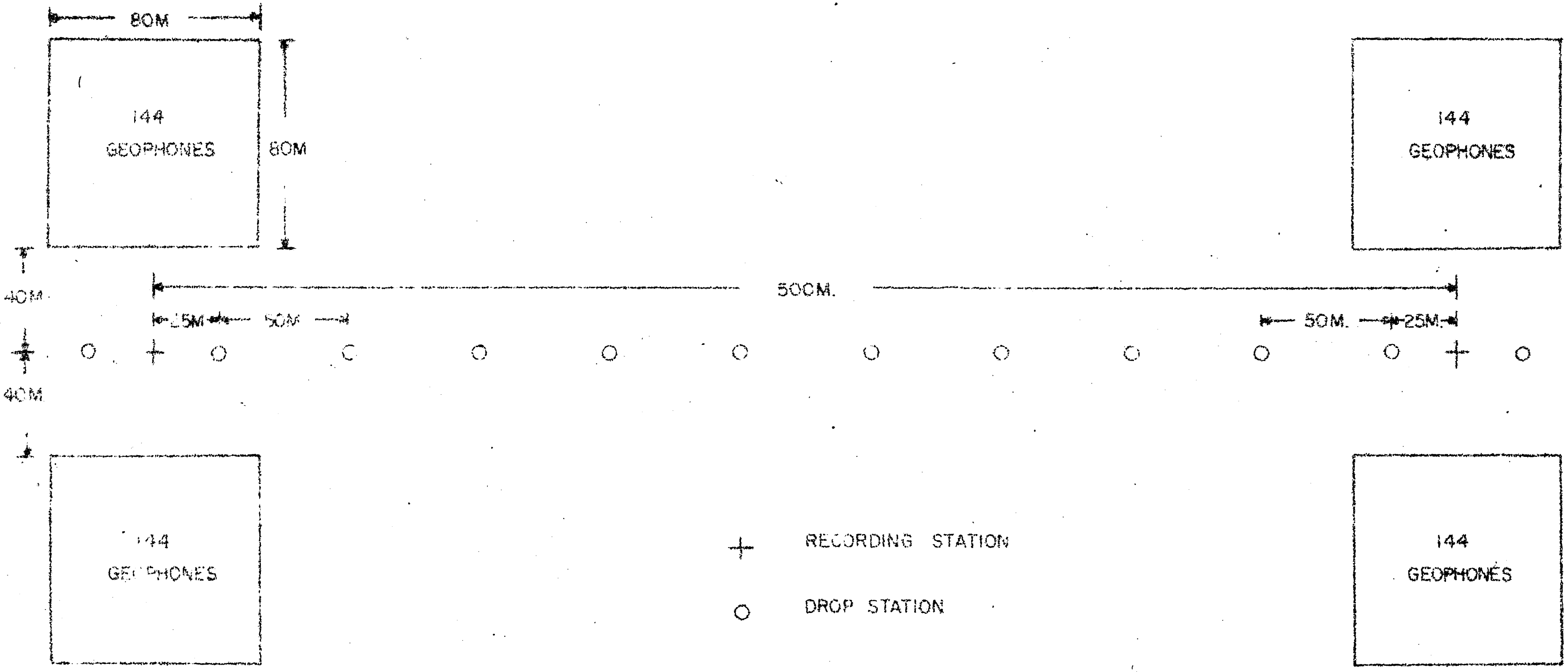
FOUR 72 DROP CIRCLES PER TRACE
(4/3 COMPOSITE)
288 GEOPHONES PER PATCH

McCOLLUM RAY INTERNATIONAL, INC.

GEOGRAPH RECORDS LIBYA, NORTH AFRICA

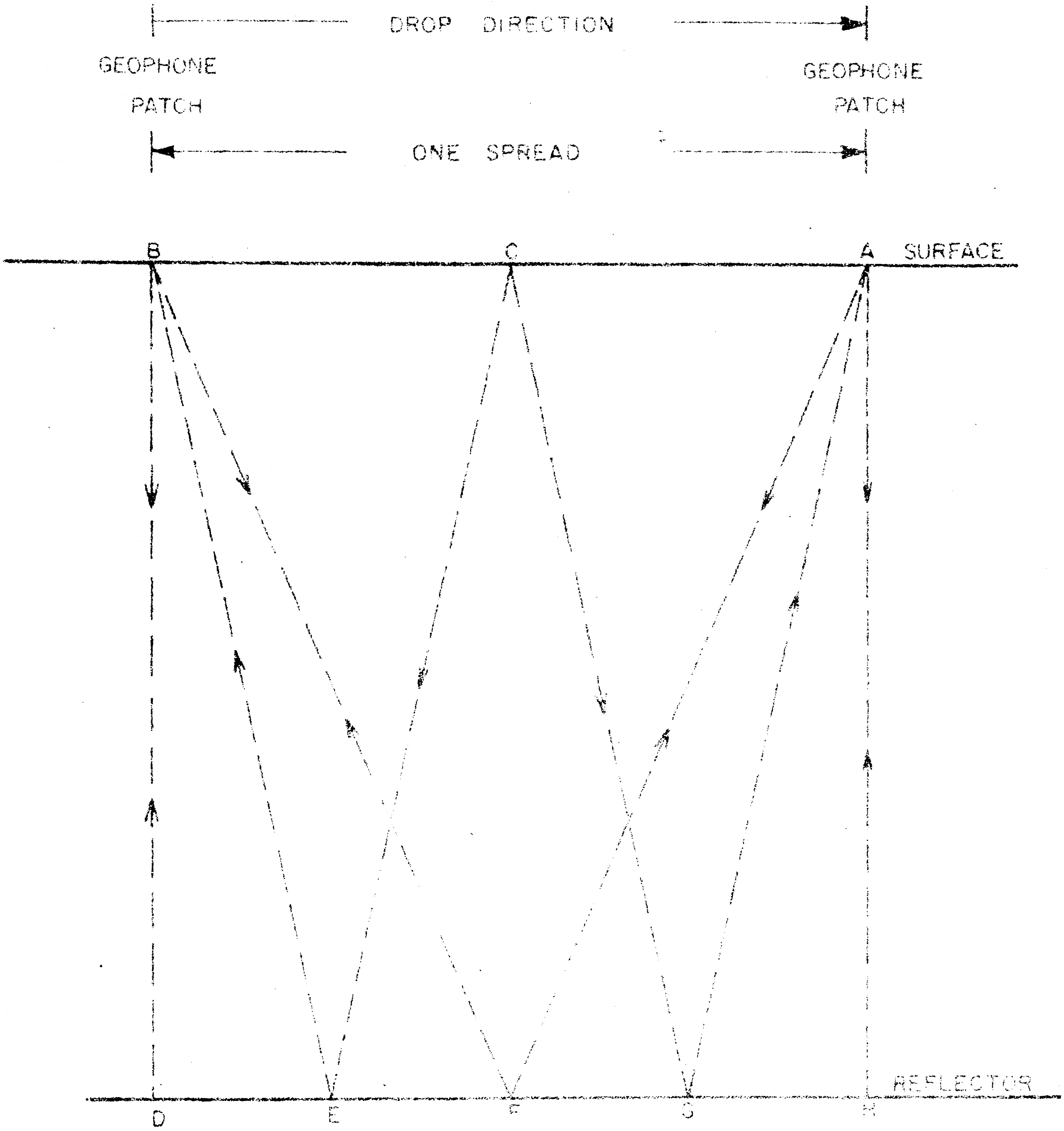


ZIG ZAG DROP PATTERN
TWO 6 DROP SEGMENTS PER TRACE (2/1 COMPOSITE)
288 GEOPHONES PER PATCH



NORMAL SPREAD LAY-OUT

FIG 6



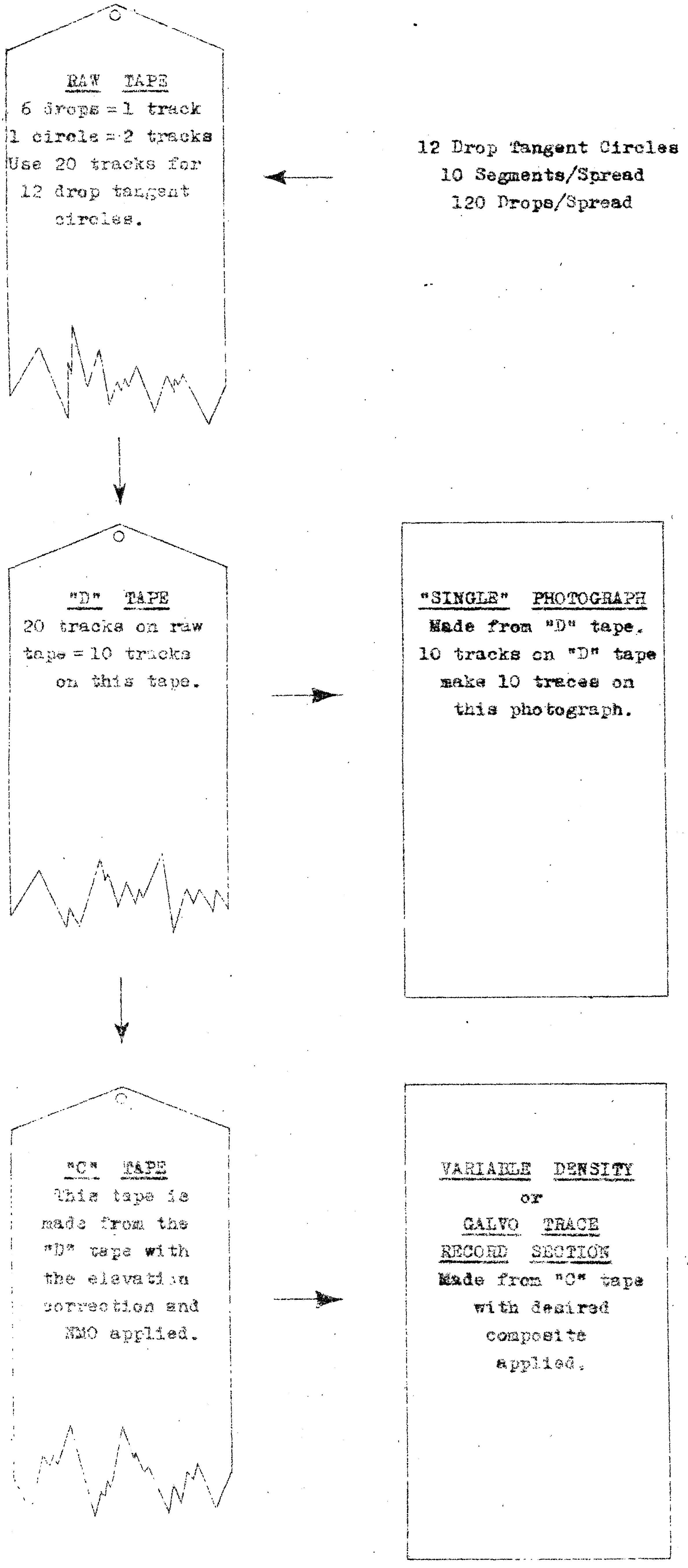
DROP B TO C —— RECORD DE AND FG

DROP C TO A ------ RECORD EF AND GH

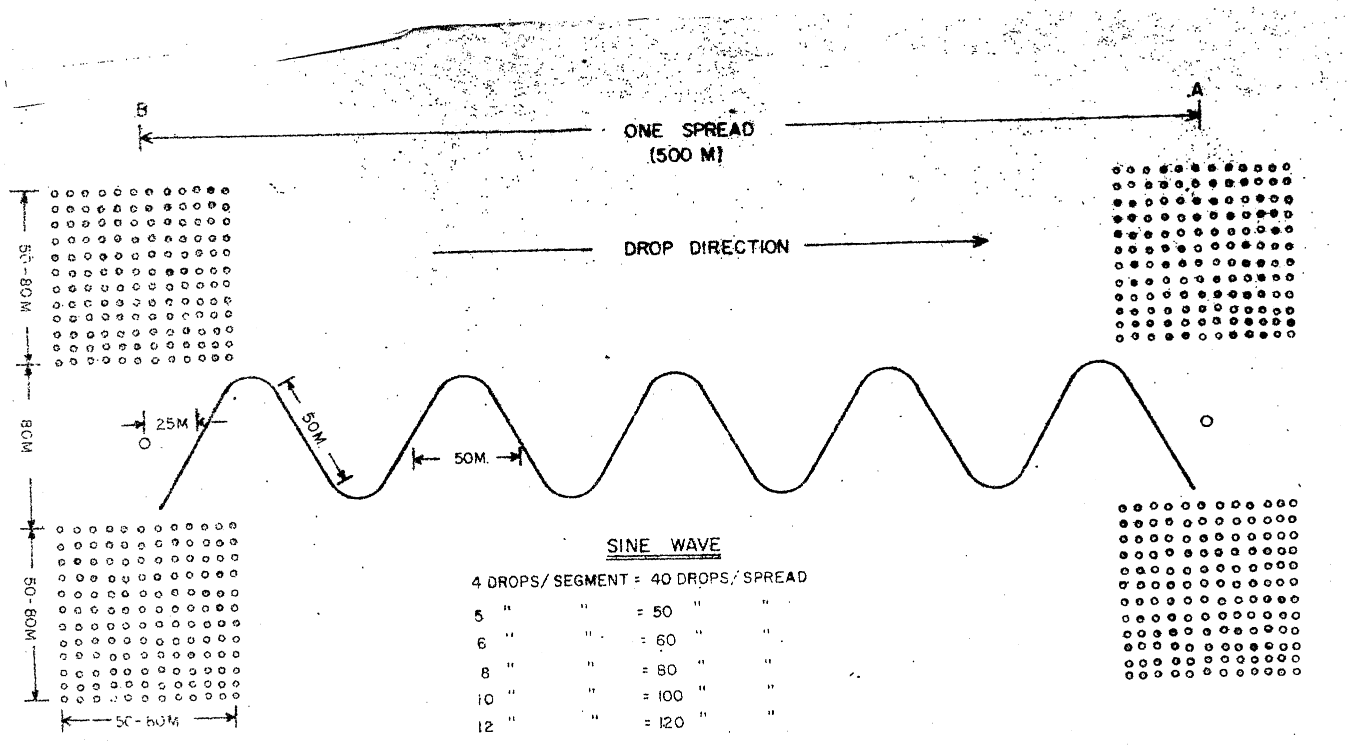
SCHEMATIC WAVE PATH DIAGRAM WITH

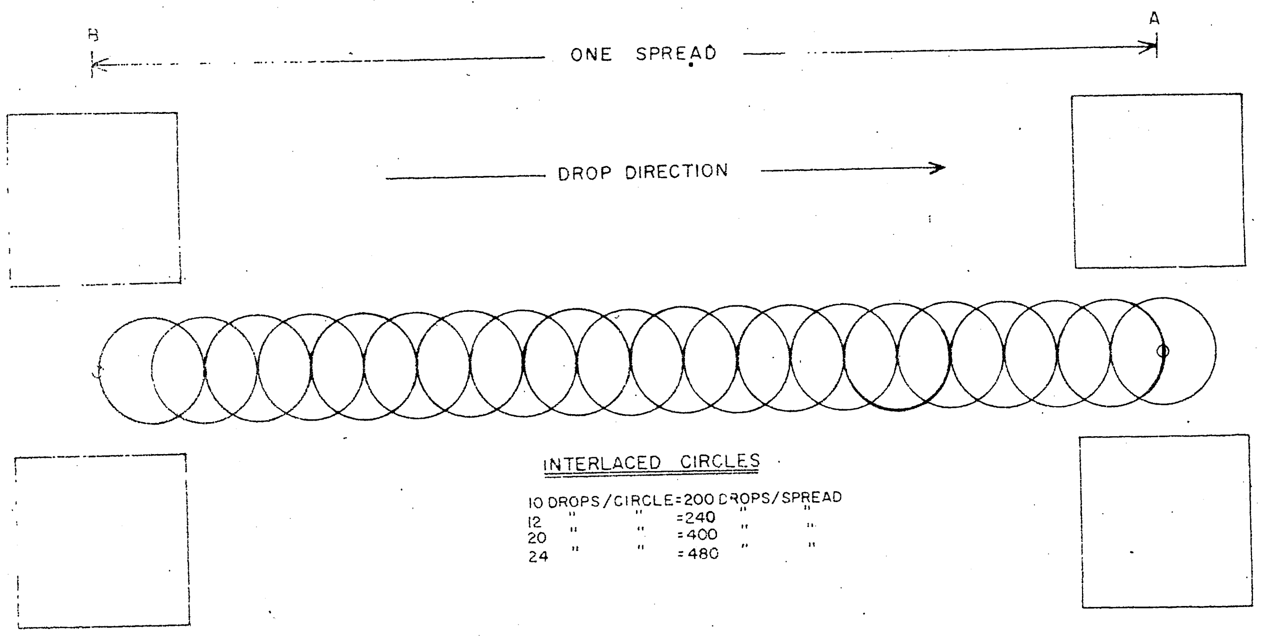
SUBSURFACE COVERAGE

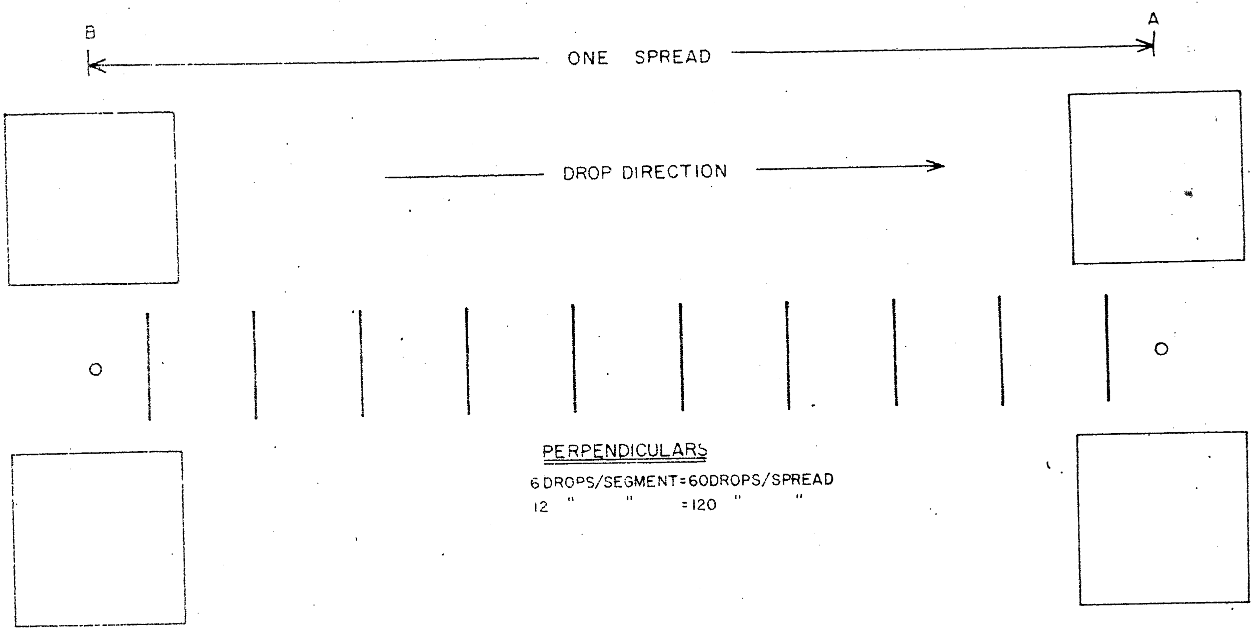
FIG 3



DATA PROCESSING PROCEDURE


B
A
ONE SPREAD
(500 M)
DROP DIRECTION
50-80M
80M
50-80M
50-80M
25M
50M
50M.
SINE WAVE
4 DROPS/ SEGMENT = 40 DROPS/ SPREAD
5 " " = 50 " "
6 " " = 60 " "
8 " " = 80 " "
10 " " = 100 " "
12 " " = 120 " "


B
A
ONE SPREAD
DROP DIRECTION
INTERLACED CIRCLES
10 DROPS/CIRCLE=200 DROPS/SPREAD
12 " " =240 " "
20 " " =400 " "
24 " " =480 " "


B
A
ONE SPREAD
DROP DIRECTION
PERPENDICULARS
6 DROPS/SEGMENT=60DROPS/SPREAD
12 " " =120 " "

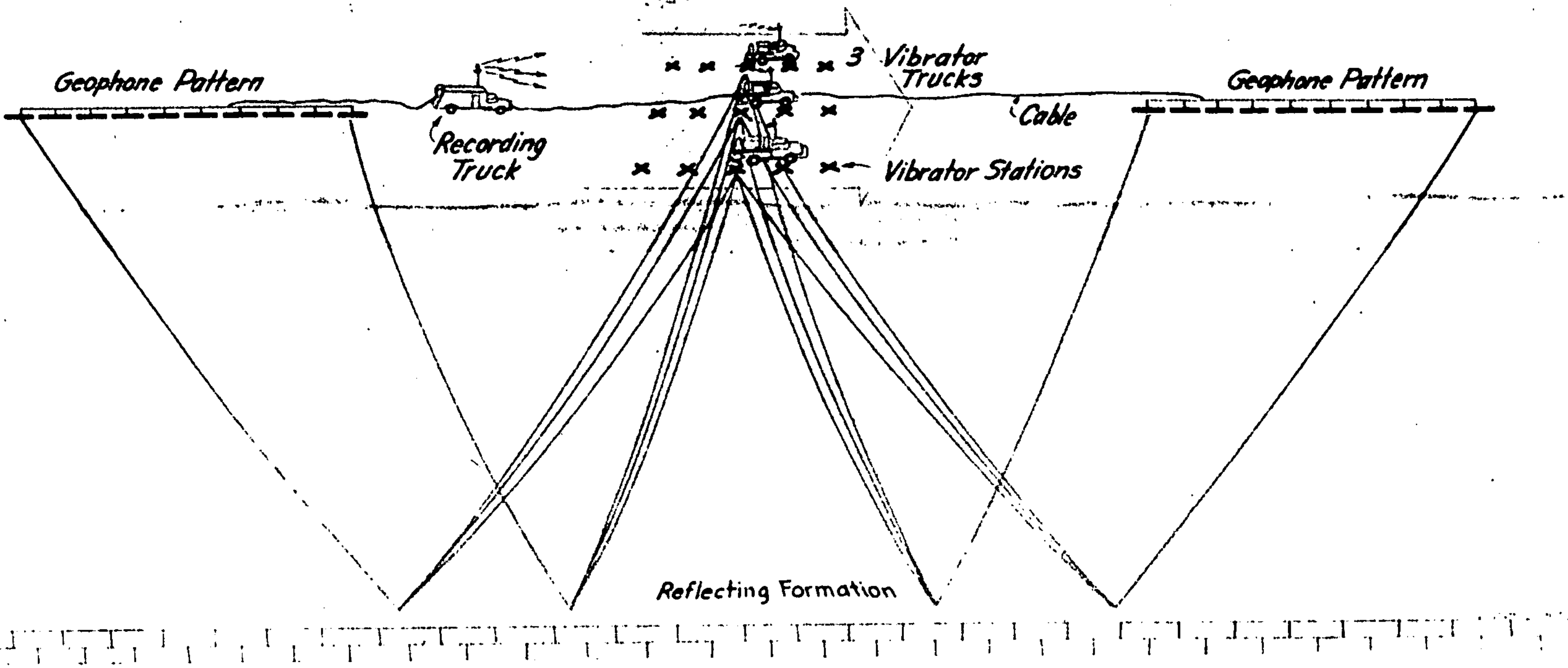
BMR Record 1962/112

"VIBROSEIS"*

STANDARD SYSTEM

Geophones are placed at the ends of the spread with the vibrators forming a pattern in the middle.

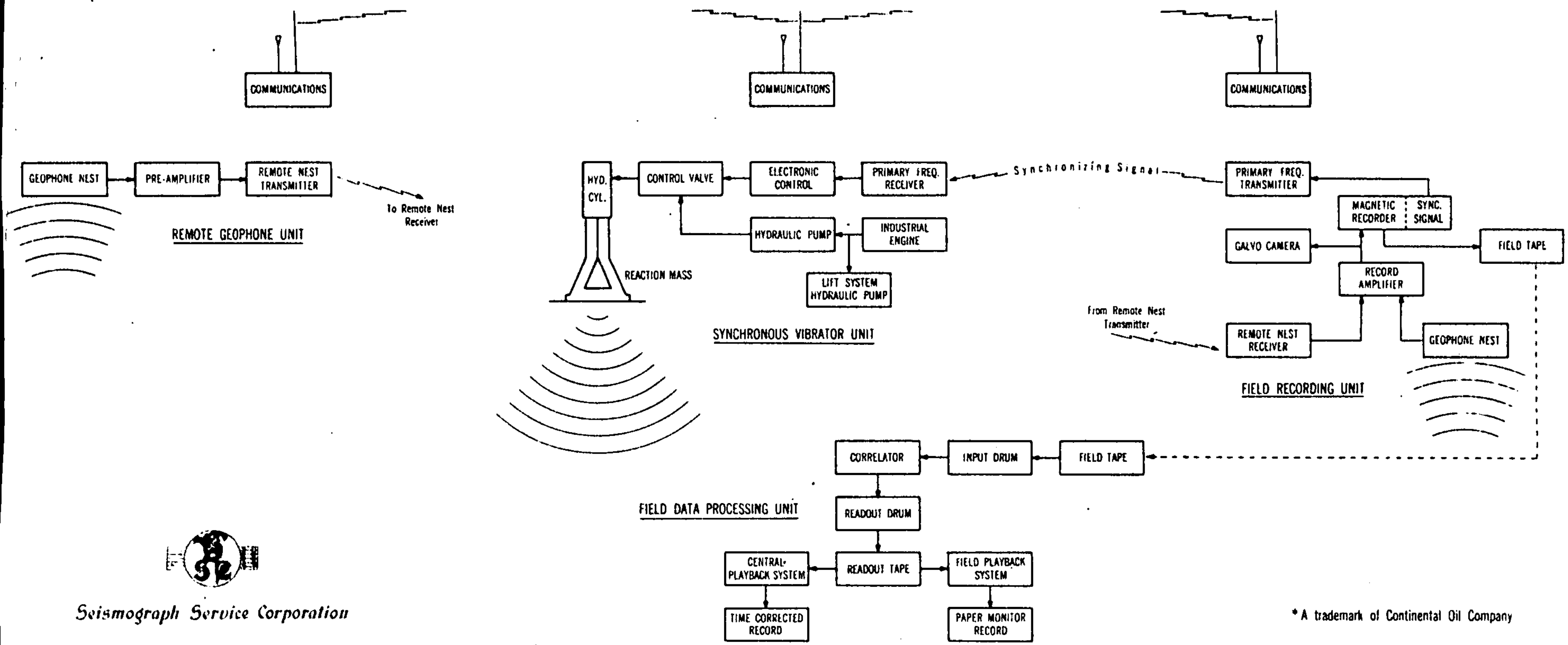
* A trademark of Continental Oil Company



Seismograph Service Corporation

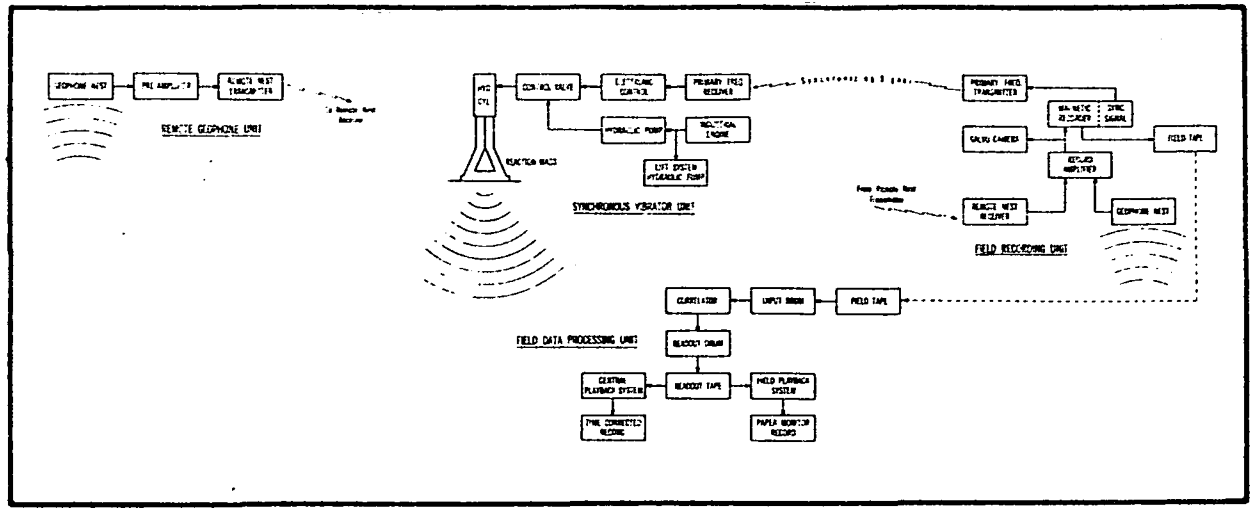
TULSA 1, OKLAHOMA, U. S. A.

"VIBROSEIS"* SYSTEM



Seismograph Service Corporation

* A trademark of Continental Oil Company



BLOCK DIAGRAM OF "VIBROSEIS"* SYSTEM

The master synchronizing signal which is composed of the desired frequency spectrum to be introduced into the earth is transmitted by radio from the Field Recording Unit to the slave Synchronous Vibrator Units. Here the radio signal is used to control the vibrator so as to insure that the input signal being introduced into the earth is an exact duplication of the master synchronizing signal as well as insuring precise in-phase matching of the vibrators operating simultaneously.

The signal is detected at two geophone arrays, one of which by the nature of the field layout is remote from the recording unit. In the case of Transposed In-Line Profiling where all the geophone outputs in a group are coupled together into one signal, the signal from the Remote Geophone Nest is radioed to the recording unit as shown in the above diagram. When, in the case of Standard In-Line Profiling, the remote spread has a separate recorded signal for each of the 10 geophone stations, a cable system is used to transmit the signal to the recording unit.

The detected signals are recorded on magnetic tape and also may be recorded on an oscillograph.

The field data stored on the magnetic tape is correlated with the original input signal introduced into the earth. The output of the correlation process is equivalent to an ordinary seismic record and is recorded on magnetic tape for use in additional "play back" equipment or from which a recording on photographic paper for hand computation in the field office may be made.

One man in the field headquarters can perform the actual correlation process on the records obtained in a field work day in less than eight hours. The introduction of the correlation step, plus the flexibility of the source and detector layouts, greatly improve reflection character, definition and identification.

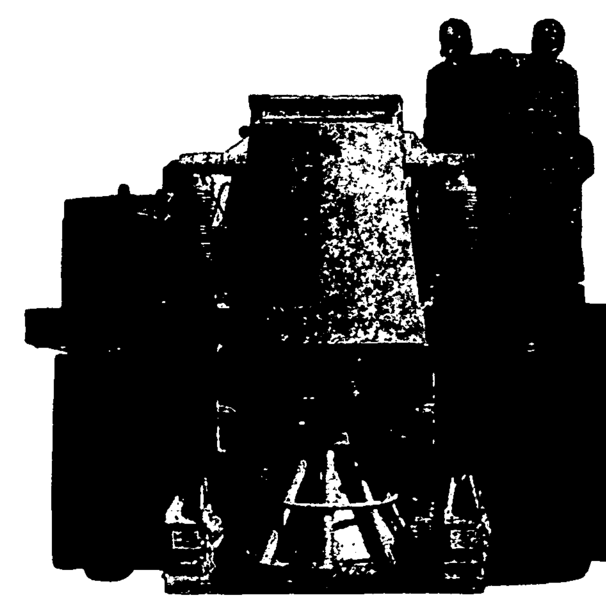
"VIBROSEIS"*

EXPLORATION SYSTEM

Offering to the geophysicist

- *CONTROL OF THE INPUT SIGNAL*
- *MULTIPLE SOURCES OF ENERGY OPERATING SIMULTANEOUSLY AND IN SYNCHRONISM*
- *CROSS CORRELATION OF RECEIVED SIGNAL WITH INPUT SIGNAL*
- *ELIMINATION OF COSTLY DYNAMITE AND DRILLING EXPENSE*
- *IMPROVED RECORD QUALITY IN DIFFICULT AREAS*

With no loss in penetration

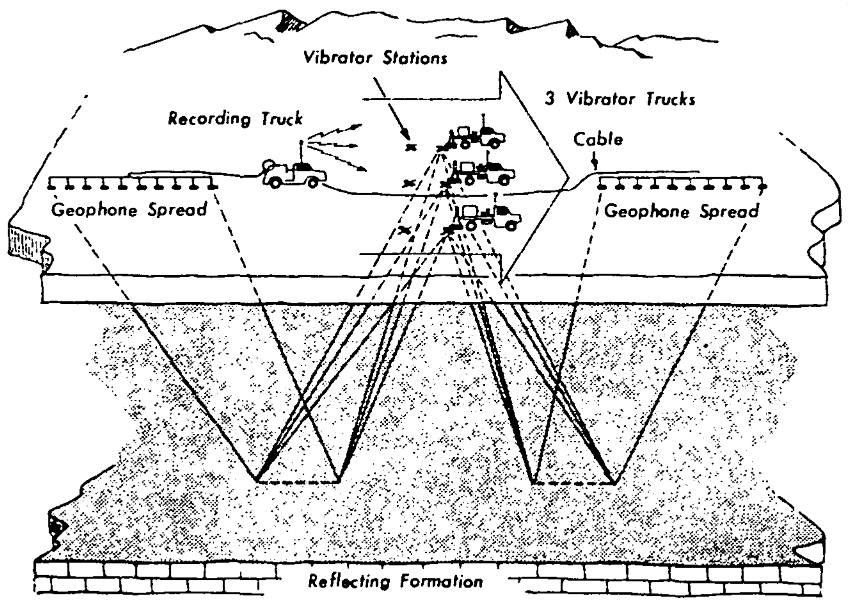


CLOSE-UP OF A HYDRAULIC VIBRATOR UNIT

* Trademark of Continental Oil Company

Seismograph Service Corporation

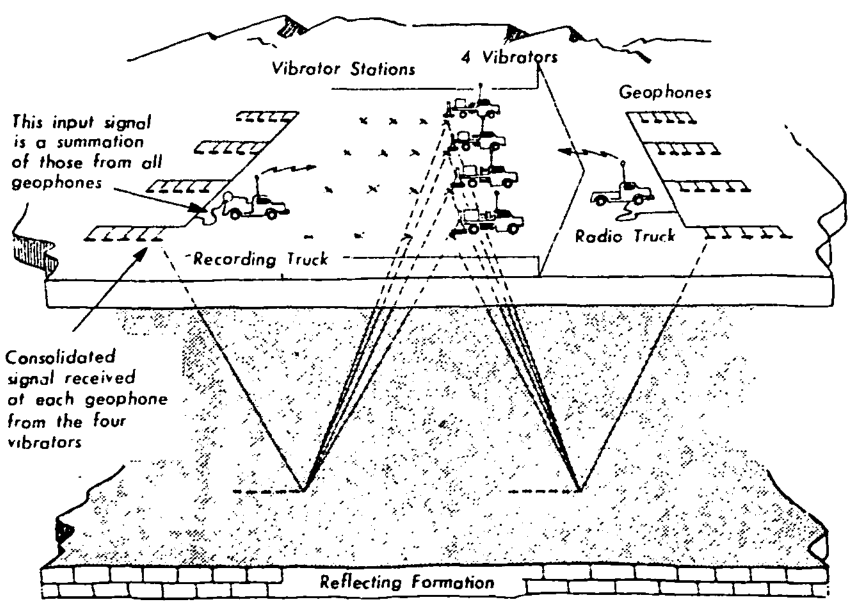
P. O. BOX 1590, TULSA, OKLAHOMA



STANDARD IN-LINE PROFILING

The vibrators occupy a pattern between two inline offset geophone spreads.

Whether standard or transposed inline profiling is used, all units move in the same direction along the profile providing maximum signal recovery with maximum coverage in minimum time.



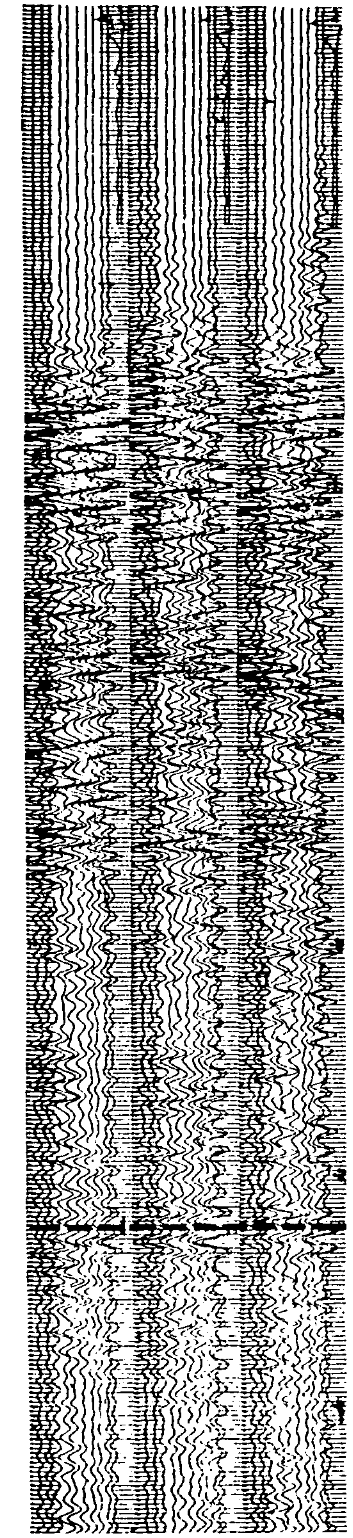
TRANSPOSED IN-LINE PROFILING

The vibrators occupy an inline spread between two offset geophone nests. (Positions of vibrators and geophones interchanged from the standard inline profiling method shown above)

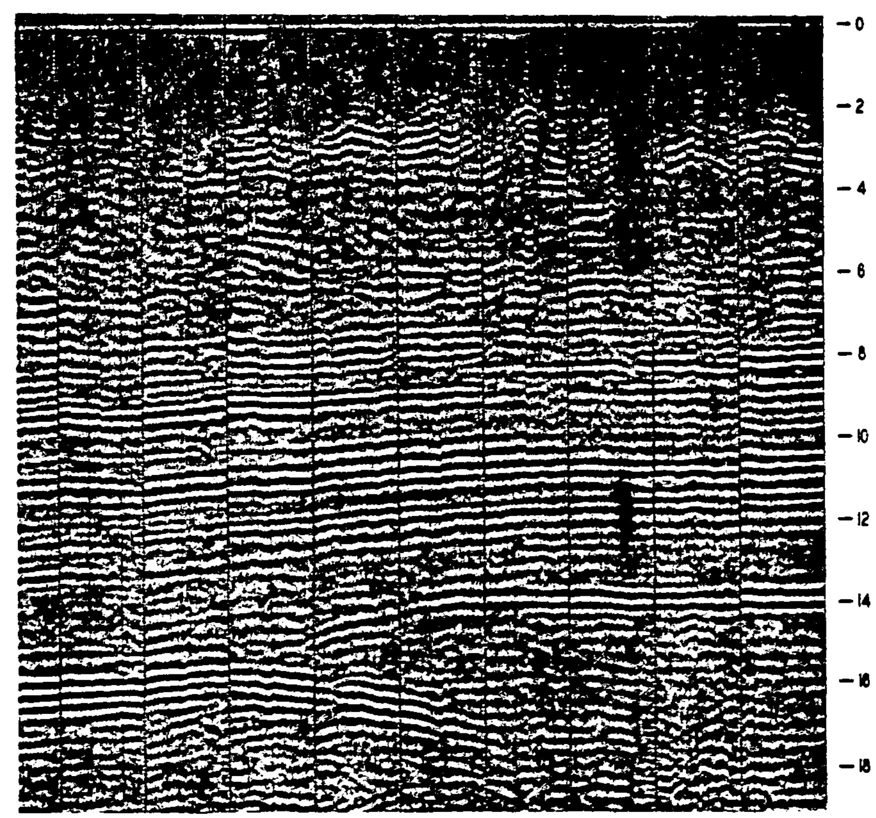
Proven results of the "VIBROSEIS"*technique have already convinced many geophysicists of the tremendous advantage of this new exploration tool in the "difficult" areas where the drilling of shotholes is prohibitive in cost and time; and where it is impossible or uneconomical to obtain permits for the drilling of shotholes and for the use of explosives.

RECORD CROSS SECTION OF A RECORDING OF THE DEVONIAN AT A TIME OF 2.6 SECONDS IN THE DEEP DELAWARE BASIN

Penetration through many layers of sedimentation with high signal to noise ratio maintained giving excellent definition and character presentation.



RECORDING DISTANCE 1350' TO 1700' APPROX.
PLAYBACK FILTER- 15-11 (24-48 CPS)
25% -50%-25% UP-DOWN MIX



VARIABLE DENSITY CROSS SECTION OF A FAULT IN CENTRAL OKLAHOMA

The flexibility of the source and detector layouts plus the correlation process greatly improve reflection character definition and identification.