ISLAMIC REPUBLIC OF PAKISTAN

RADIOACTIVE MINERAL RESOURCES DEVELOPMENT IN PAKISTAN

—SURVEY REPORT—

October, 1972

OVERSEAS TECHNICAL COOPERATION AGENCY
GOVERNMENT OF JAPAN

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FOREWORD

The Government of Pakistan requested the Government of Japan to undertake car-borne radiometric survey of a part of the country with the purpose of developing the uranium resources of Pakistan in accordance with the recommendations of West Pakistan Mineral Resources Development Survey Team sent by the Overseas Technical Cooperation Agency in February 1971. In compliance with the above request, the Japanese Government entrusted the Overseas Technical Cooperation Agency with the execution of the project in 1972.

The Agency organized a survey team headed by Dr. Michiya Kouno, Senior Geologist of the Geological Survey of Japan, and consisting of seven members, and dispatched the team to Pakistan for forty (40) days from 13 May to 21 June 1972.

The team discussed matters related to the survey with the staff of the Ministry of Fuel, Power and Natural Resources, Pakistan Atomic Energy Commission, and the Geological Survey of Pakistan. And conducted car-borne radiometric survey mainly in the western part of the Makran Coast in southwestern Pakistan.

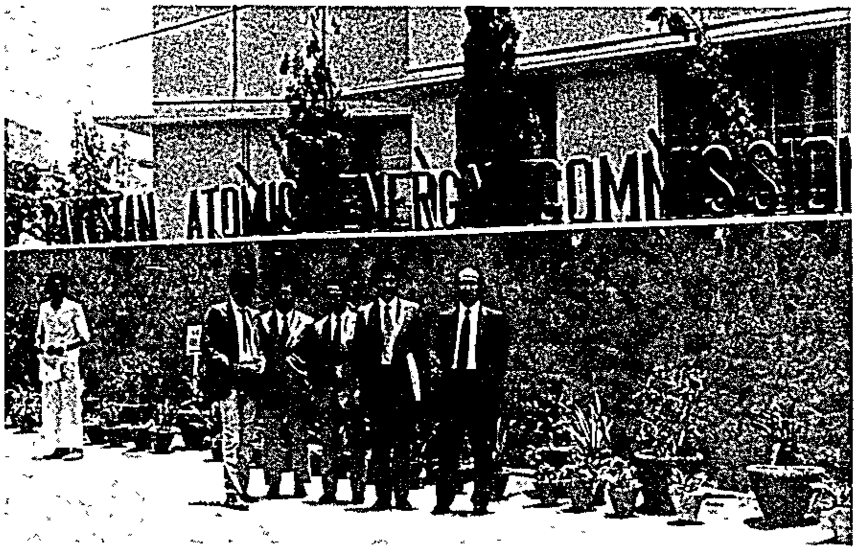
After careful study of the results obtained through the survey, the team recommends a detailed radiometric survey of the formations correlated to the Siwalik group and the formations immediately underlying this group in the above area, and submits the following report.

It is my sincere wish that this report will contribute to the economic development, especially the development of uranium resources of Pakistan and also to the furtherance of the friendship between our two countries.

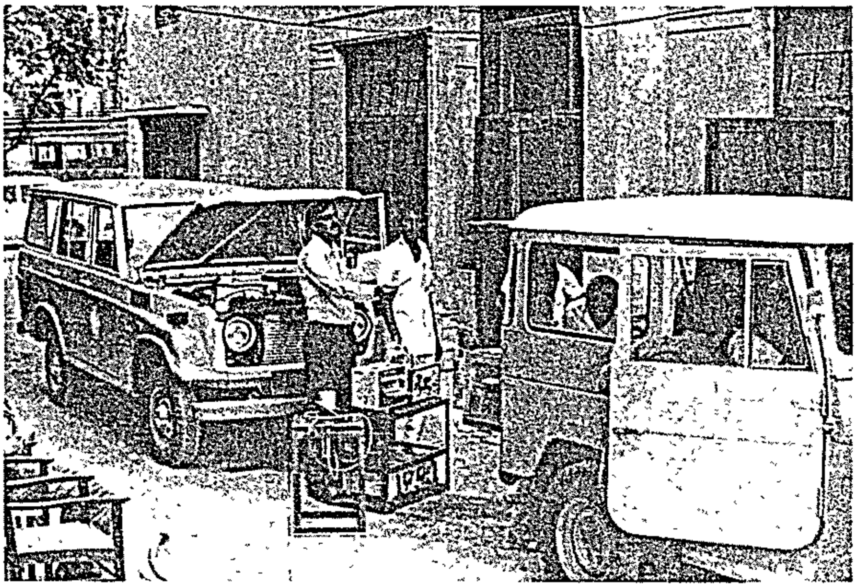
I would like to express my sincere gratitude to the authorities of the Pakistan Government who whole-heartedly cooperated with this survey.

Octobar 1972

Keiichi Tatsuke
Director General
Overseas Technical
Cooperation Agency

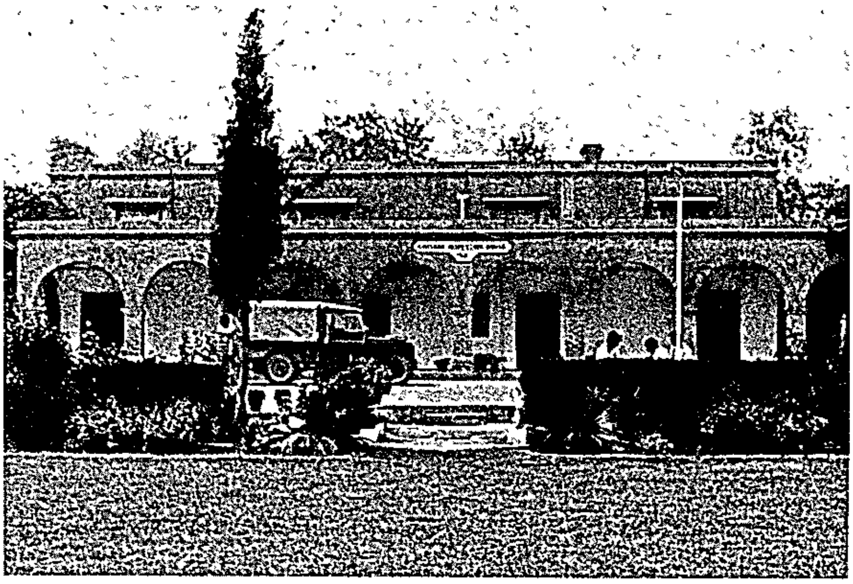


1. Team members in front of PAEC. (Karachi)



2. Installing car-cooler and car-borne survey meter. (Lahore)

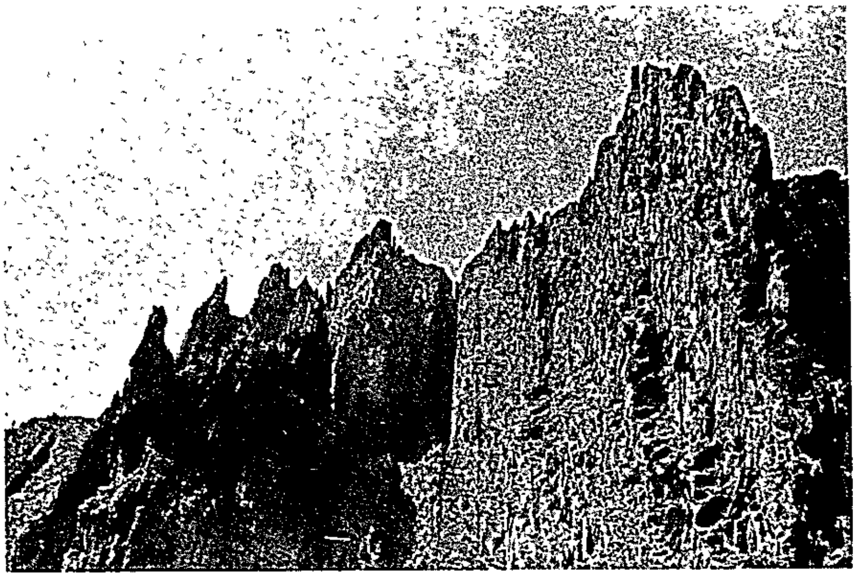
3. Surveying the Siwalik group, Rawalpindi - Khushab.



4. Khushab Inspection House. Similar facilities were used in other areas for lodging.

5. The Siwalik group near Dera Ghazi Khan.

6. Exploration camp of PAEC at Dera Ghazi Khan. The rocks of the hill in background is Siwalik group.



7. Formation corresponding to the Siwalik group distributed between Bela - Awaran. Parts of the sandstone showed radioactivity three times the natural count.

8. Talar sandstone found between Turbat - Pasni.

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1. INTRODUCTION

1-1 Circumstances Leading to the Dispatch of the Survey Team and the Objectives of the Team

In compliance with the request from the Government of Pakistan, the Overseas Technical Cooperation Agency (OTCA) sent two geologists under the leadership of Dr. Hideo Takeda to West Pakistan for forty five (45) days from 10 February 1971 with the express purpose of obtaining basic data concerning the development of mineral resources of West Pakistan. After field survey, and investigation of existing data, this team recommended (1) uranium survey, car-borne radiometric survey of areas where Siwalik group and other formations of the same age are distributed, (2) nickel and chromium survey, (3) air-borne magnetic survey; as the most suitable projects for technical cooperation of the Japanese Government in the field of mineral resources development.

The Pakistan Government, in line with the above recommendation requested car-borne radiometric survey for the purpose of uranium prospecting.

The Japanese Government agreed to send a team of experts in compliance with this request and entrusted OTCA to carry out this project. OTCA fully reallizing the importance of uranium resources development, organized and dispatched a team for forty (40) days between 13 May and 21 June 1972.

1-2 Members of the Survey Team

Chief	Dr. Michiya Kouno	Senior Geologist, Geological Survey of Japan
	Mr. Tatsumi Miyoshi	Mining Section, Mines and Coal Bureau, Ministry of International Trade and Industry
	Mr. Koichiro Daimaru	Senior Geologist, Nikko Exploration and Development Co.
	Mr. Kenji Ito	Senior Geologist, Power Reactor and Nuclear Fuel Development Corporation
	Mr. Katsuhiro Otani	Senior Geologist, Sumiko Consultants Co.

Mr. Toshio Sakasegawa	Geologist, Metallic Minerals Exploration Agency of Japan
Mr. Yukihisa Sakurada	Coordinator, Overseas Technical Cooperation Agency

1-3 Circumstances Leading to the Selection of the Surveyed Area

Since the discovery of radioactive anomalies in the sandstone formations of the Siwalik group in the Dera Ghazi Khan district in the central part of West Pakistan by J. A. Reinemund and others of the United States Geological Survey in 1959, the vicinity of Dera Ghazi Khan has been surveyed for radioactive anomalies by the geologists of the Pakistan Geological Survey, French Mission, and the United States Geological Survey. Since 1968, detailed survey including drilling and trenching has been conducted by the Pakistan Atomic Energy Commission and many radioactive anomalies have been confirmed in the Siwalik group in the area from Dera Ghazi Khan northward to Dera Ismail Khan. At present, detailed prospecting is being carried out in the Dera Ghazi Khan area by the assistance of UNDP.

Radioactive anomalies are distributed in north-south direction along a 120 mile strip from Dera Ghazi Khan to Dera Ismail Khan, and the Siwalik group is the most important host rock for sedimentary uranium concentration in Pakistan.

The distribution of the Siwalik group and other formations of the same geologic age can be divided into the following areas from geologic structure, i. e., north, central, and southwest Pakistan. In north Pakistan, these formations are distributed widely in east-west direction with Rawalpindi in the center; in central Pakistan, they are distributed in north-south direction along the eastern side of the Sulaiman Range with the centre near Dera Ghazi Khan and the distribution forms an arc and reaches Quetta in the southwestern part. In southwest Pakistan, they are distributed on the southern and eastern sides of the Makran Coast Range in approximately north-south direction in the north and in east-west direction facing the Arabian Sea in the central and western parts of this area.

The above three areas are considered appropriate for car-borne radiometric survey. But in the area west of Rawalpindi in north Pakistan, reconnaissance survey by portable radiometry has been completed by the Pakistan Atomic Energy Commission

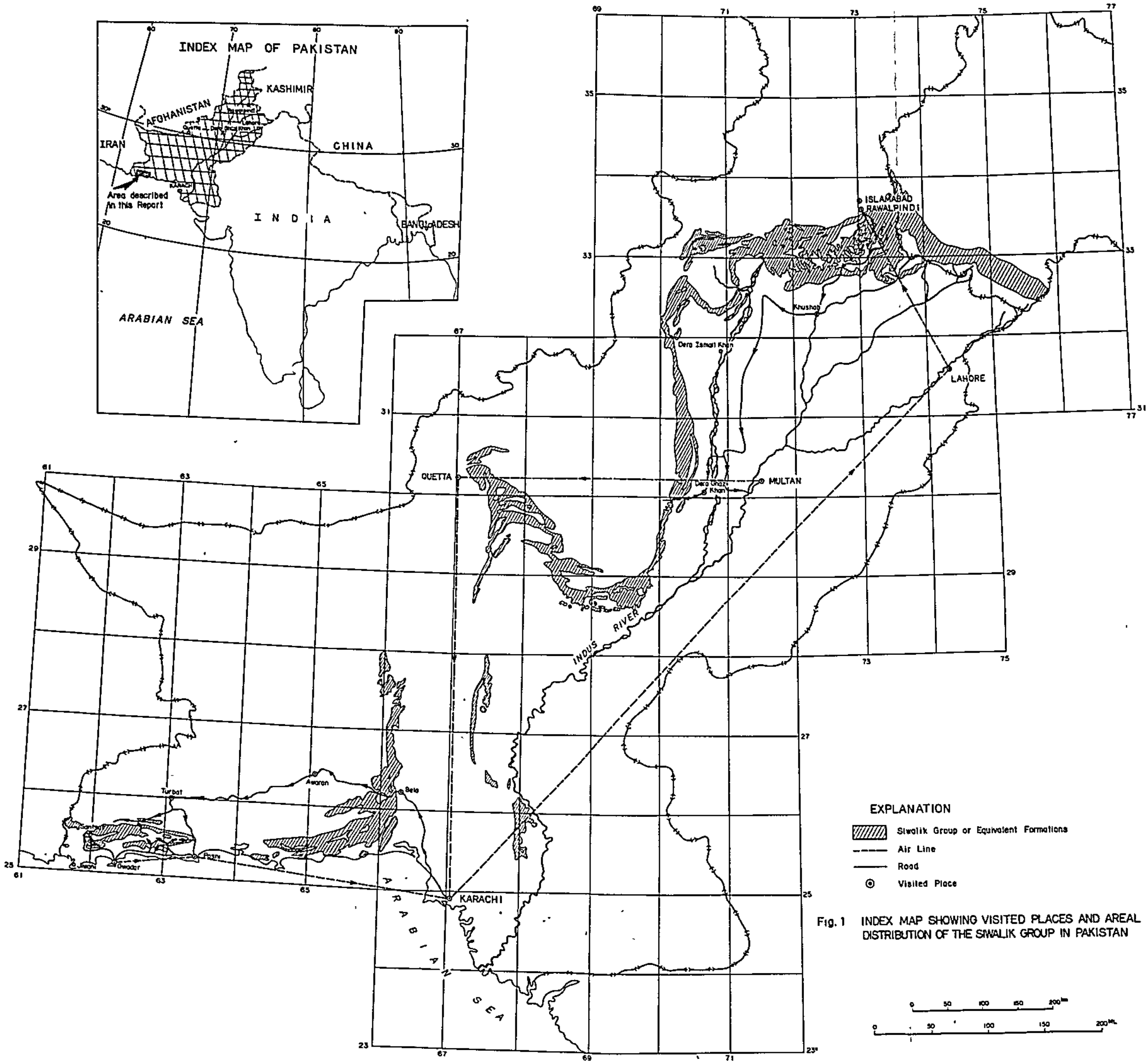


Fig. 1 INDEX MAP SHOWING VISITED PLACES AND AREAL DISTRIBUTION OF THE SIWALIK GROUP IN PAKISTAN

and the adjacent eastern area is difficult for field work as it is in the border area. Also the area between Dera Ghazi Khan and Dera Ismail Khan has been surveyed as mentioned before, and field work is difficult in the southern part as it is in the Tribal Area. Thus remaining area worth the radiometric survey is in southwest Pakistan along the Makran Coast Range, and the western Makran Coast was selected after discussion with the Pakistan Atomic Energy Commission mainly because of the development of the road system.

1-4 Itinerary of the Team

No. of days.	Date	Day of Week	
1.	May 13	Sat.	Tokyo ⟶ Karachi (by air).
2.	14	Sun.	Kouno & Sakurada, Karachi ⟶ Rawalpindi (by air).
3.	15	Mon.	Kouno, Sakurada, conference at Japanese Embassy. Rawalpindi ⟶ Karachi (by air). Daimaru. Ito. Otani. Sakasegawa, conference at Pakistan Atomic Energy Commission (PAEC).
4.	16	Tues.	Courtesy call to PAEC and Japanese Consulate General.
5.	17	Wed.	Customs formalities of instruments from Japan, and shipment to Lahore.
6.	18	Thurs.	Karachi ⟶ Lahore (by air).
7.	19	Fri.	Courtesy call and conference at Atomic Energy Minerals Centre. (AEMC).
8.	20	Set.	Conference at AEMC and preparation of instruments.
9.	21	Sun	Lahore ⟶ Rawalpindi (by air).
10.	22	Mon.	Courtesy call to Ministry of Science and Technology, Ministry of Fuel, Power and Natural Resources, and Japanese Embassy.
11.	23	Tues	Rawalpindi ⟶ Khushab. Survey of the Siwalik group by land cruisers.

12.	24	Wed.	Khushab ⟶ Dera Ghazi Khan by land cruisers.
13.	25	Thurs.	Dera Ghazi Khan ⟶ Multan. Survey of uraniferous formations by land cruisers.
14.	26	Fri	Multan ⟶ Quetta (by air).
15.	27	Sat	Discussion at Geological Survey of Phkistan Quetta ⟶ Karachi (by air).
16.	28	Sun.	
17.	29	Mon.	Conference with PACE on logistics of field work.
18.	30	Tues.	" "
19.	31	Wed.	Karachi ⟶ Bela by land cruisers.
20.	June 1	Thurs.	Bela ⟶ Awaran by land cruisers, car-borne radiometry.
21	2	Fri.	Awaran ⟶ Turbat by land cruisers.
22	3	Sat.	Car-borne radiometry, vicinity of Turbat.
23	4	Sun.	" " " "
24	5	Mon.	Turbat ⟶ Pasni by land cruisers, radiometry.
25	6	Tues.	Car-borne radiometry, vicinity of Pasni
26	7	Wed.	" " " "
27	8	Thurs.	Pasni ⟶ Gwadar by land cruisers, radiometry. Miyoshi, Tokyo ⟶ Karachi (by air).
28	June 9	Fri.	Car-borne radiometry, vicinity of Gwadar. Miyoshi Karachi ⟶ Rawalpindi (by air).
29	10	Sat.	Car-borne radiometry, vicinity of Gwadar. Miyoshi, corference with Ministry of Fuel, Power and Natural Resources, and Japanese Embassy.
30	11	Sun.	Gwadar ⟶ Karachi (by air).
31	12	Mon.	Report to Japanese Consulate General. Miyoshi, Rawalpindi ⟶ Quetta (by air). Conference with Government of Baluchistan.

32	13	Tues.	Report writing. Study of survey results. Miyoshi, Quetta ——→Karachi (by air).
33	14	Wed.	Dismantling of survey instruments from vehicles. Packing equipment to be shipped.
34	15	Thurs.	Assembled data for report to PAEC.
35	16	Fri.	Report to PAEC.
36	17	Sat.	Kouno, Daimaru, Karachi ——→ Rawalpindi report to Japanese Embassy. Ito, Otani, Sakasegawa, Miyoshi, Sakurada, customs formalities for equipment to be shipped to Japan.
37	18	Sun.	
38	19	Mon.	Courtesy call on PAEC and Japanese Consulate General.
39	20	Tues.	Karachi ——→ Bangkok (by air).
40	21	Wed.	Bangkok ——→ Tokyo (by air).

1-5 Acknowledgements

During the course of the present survey, the team was greatly assisted by the kind cooperation of many Pakistan organizations and personnel, especially the Economic Coordination and External Assistance Division of the President's Secretariat and the Pakistan Atomic Energy Commission. And during the field work, the staff of the Headquarters of the Atomic Energy Commission in Karachi and the Atomic Energy Minerals Centre accompanied the team, and with their assistance it was possible to complete the survey without mishap. The team was able to conduct the survey efficiently in a relatively short period of time thanks to the assistance offered by the Government of Pakistan and the team expresses its deep gratitude.

Also Ambassador Sono, Messr. Someya and Kikukawa and other staff members of the Japanese Embassy and Consul General Hara, and Consul Ueda and other staff members of the Japanese Consulate General in Karachi had very kindly offered valuable assistance for the survey and also for collection of various information. The members of the team express their gratitude.

The Pakistani personnel from the Pakistan Government who cooperated with the survey through valuable discussion, gathering information, and the field work are as follows.

Ministry of Science and Technology (Islamabad)

Dr. Manzur Ahmad	Joint Secretary

Ministry of Fuel, Power and Natural Resources (Islamabad)

Mr. I.G. Nasir Khan	Additional Secretary

Atomic Energy Commission (Karachi)

Mr. Munir Ahmad Khan	Chairman
Mr. K. M. Aslam	Director, Directrate of Nuclear Minerals
Mr. S. M. Hasan	Senior Geologist (Joined field work)

Atomic Energy Commission, Minerals Centre (Lahore)

Mr. M. Aslam	Director
Mr. Javid Durrani	Geophysicist (Joined field work)
Mr. Naqi Abidi	Geologist (Joined field work)
Mr. M. A. Rahman	Senior Geologist
Dr. M. Shabbir	

Geological Survey of Pakistan (Quetta)

Dr. Abdul Mannan Khan	Director General
Dr. Tayyab Ali Shah	Deputy Director General
Mr. M. W. Iqbal	Director, Publication
Mr. J. M. Master	Deputy Director General
Mr. Mohammad Ali Mirza	Geophysicist

Makran District Commission (Turbat)

Mr. Ammanullah Khan	Deputy Commissioner

Atomic Energy Commission (Gwadar)

Mr. Zafeer Uddin	Project Director, Solar Desalination Plant

2. RADIOMETRIC SURVEY

2-1 Locality and Access

The western part of the Makran Coast, the area surveyed, lies near the Iranian border, is bounded by Turbat, Pasni, Gwadar, and Santsar, it is 92 miles in east-west, 32 miles in north-south directions and the total area is about 3,000 square miles. The area is at long. 61° 50' - 62° 30' E., and lat. 25° 05' - 26° N., and is 225 miles as the crow flies from Karachi, the largest city of Pakistan, and also 10 miles from the Iranian border.

The area can be reached by road, mostly unpaved, from Karachi taking three days by land cruiser, and also three flights are scheduled each week between Karachi Airport and Gwadar, Pasni Airports in the area and Jiwani which lies to the west of the area. During the field work the itinerary of the team was as follows.

May 31	Karachi - Bela	123.5 miles	land cruiser
June 1	Bela - Awaran	109.0 "	"
June 2	Awaran - Turbat	134.2 "	"
June 11	Gwadar - Pasni - Karachi, 2 hrs 15 min. (aircraft; Fokker Friendship)		

Within the surveyed area, there is a trunk road, almost all unpaved, linkning Turbat, Pasni, Gwadar, and Santsar, this road is passable by trucks, but otherwise there are very few roads passable by land cruiser and even those few roads were constructed in the desert or along the dry river beds, and thus the area covered by this car-borne radiometric survey was limited.

2-2 Topography and Climate

The surveyed area is elongated in east-west direction parallel to the direction of the geologic structure of the area. It belongs to the southwestern part of the Makran Coast Range which is 300 miles in east-west and 50 - 70 miles in north-south direction and is a platform of 2,000 to 3,000 feet above sea-level. It faces the Arabian Sea across a desert in the southern part. The Talar sandstone which consists mostly of sandstone forms the cliffs and hills, the Parkini mudstone and the Chatti mudstone which occur immediately above and below the Talar sandstone form the top of the platform, wide valleys or the gentle hills in the desert, and thus the geological conditions are well reflected in the topography. Also as the general geology consists generally of alternations of sandstone and mudstone, typical cuesta topography is observed. The drainage pattern in this area is either parallel or perpendicular to the range, and most of the paths is usually dry with water flowage only during the rainy season.

The Makran coastal area including the surveyed area is extremely arid with annual rainfaill of 130 - 150 mm, and it consists of platforms with almost no vegetation and of sand or gravel deserts. The present survey was undertaken during the hottest time of the year and the temperature rose to more than 50° C outdoors. Turbat which is somewhat inland has low humidity while Pasni and Gwadar have higher humidity owing to the humid wind from the sea.

2-3 Radiometric Instruments

The radiometric instruments used were all scintillation counters manufactured by Nihon Musen Irigaku Kenkyujo. They included one car-borne survey meter, two man-borne survey meters which are disigned to be packed on the back, and for portable scintillation counters.

(1) Car-borne Survey Meter

The power is obtained from the car battery and the current is fed through inverter (inverts direct current to alternating current) into the voltage stabilizer. The detector consists of NaI (Tl) 3" x 3" scintillater and Dumont #6363 photomultiplier. The monitor is equipped with a rate meter with an alarm system which can be adjusted to sound at every count or at every 1, 000, 2, 000........... counts and the radioactivity can be judged audibly. The basic electric circuits of this instrument are shown in Fig. 2. The intensity of the radioactivity is indicated by cpm unit and is recorded by a recorder (Toyo Denpa Kogyo Co.) which sends charts at constant speed. The recorder for car-borne survey when used in Japan is powered by a flexible wire connected to the transmission of the vehicle so that the speed of the chart corresponds to that of the vehicle.

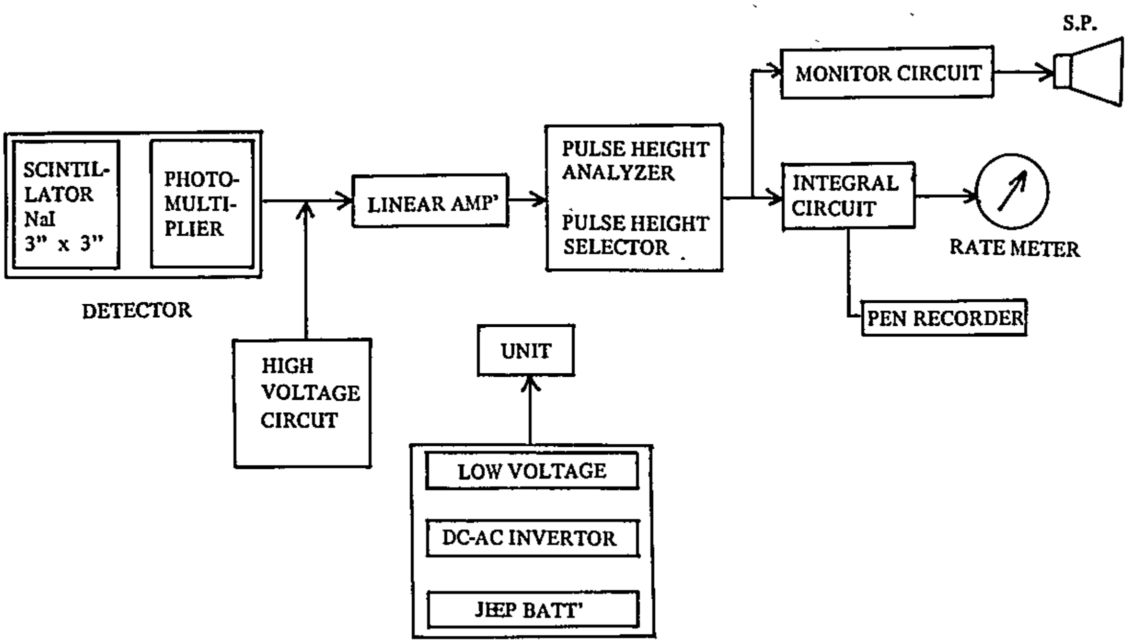


Fig. 2 Block diagram of the Car-borne Survey Meter

(2) Man-borne Survey Meter

This instrument is powered by dry cells and is designed to be carried on the back or slung from the shoulder during field work. The detector consists of NaI (Tl) 2" x 2" scintillater and Toshiba 7696 photomultiplier. The radioactivity is indicated in cpm unit. The basic electric circuits are shown in Fig. 3. During the present survey, this instrument was connected to a pen recorder and mounted on a land cruiser.

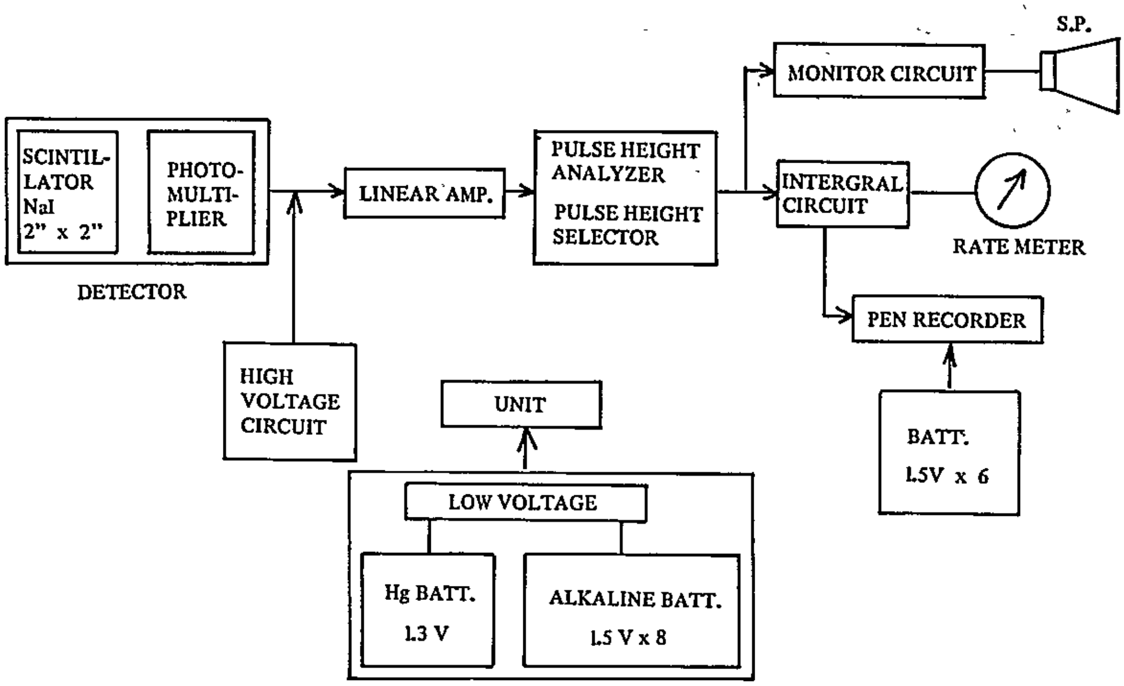
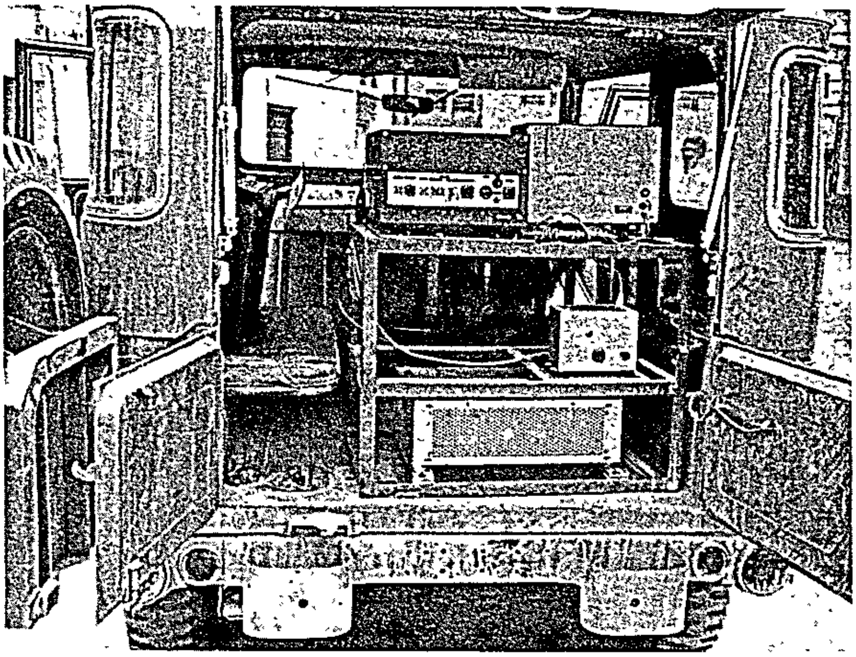


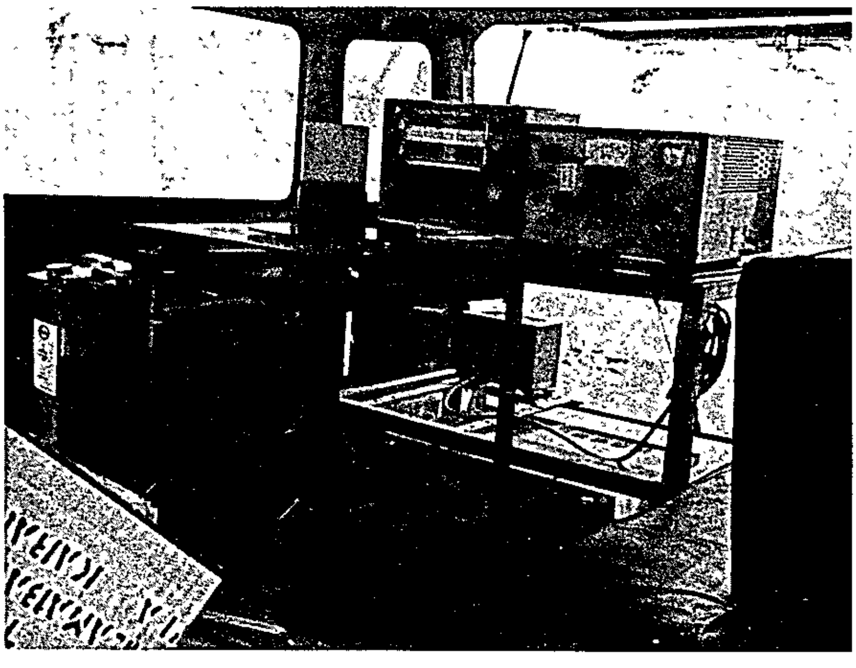
Fig. 3 Block diagram of the Man-borne Survey Meter, Type TCS-R12-805

(3) Portable Scintillation Counter

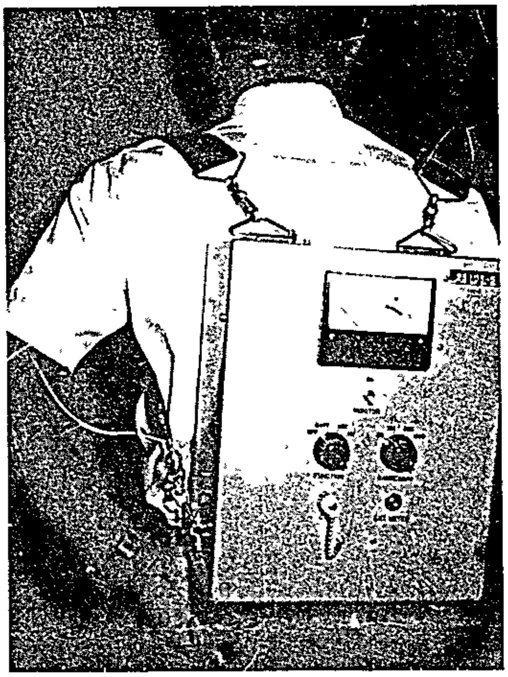
This instrument is powered by mercury cells of several volts and is transitorized, compact, and light weight with a built-in monitor and count rate meter. The sensitivity to γ -rays is higher than Geiger Muller conters and thus it is widely used in field work. The detector consists of NaI (Tl) 1" x 1" crystal and Toshiba PH-53 photomultiplier. The basic circuits are shown in Fig. 4. The radioactivity is indicated in μr/h unit. This was used for detailed survey of radioactive anomalous areas and for comparison of the measurement of the outcrops with the other two types.

Car—borne Survey Meter

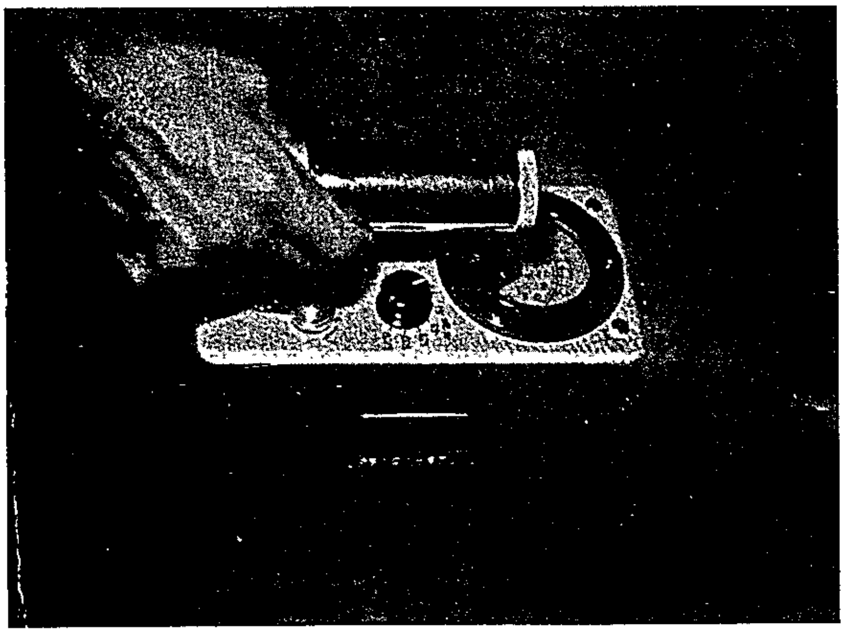




Man—borne Survey Meter



Portable Scintillation Counter



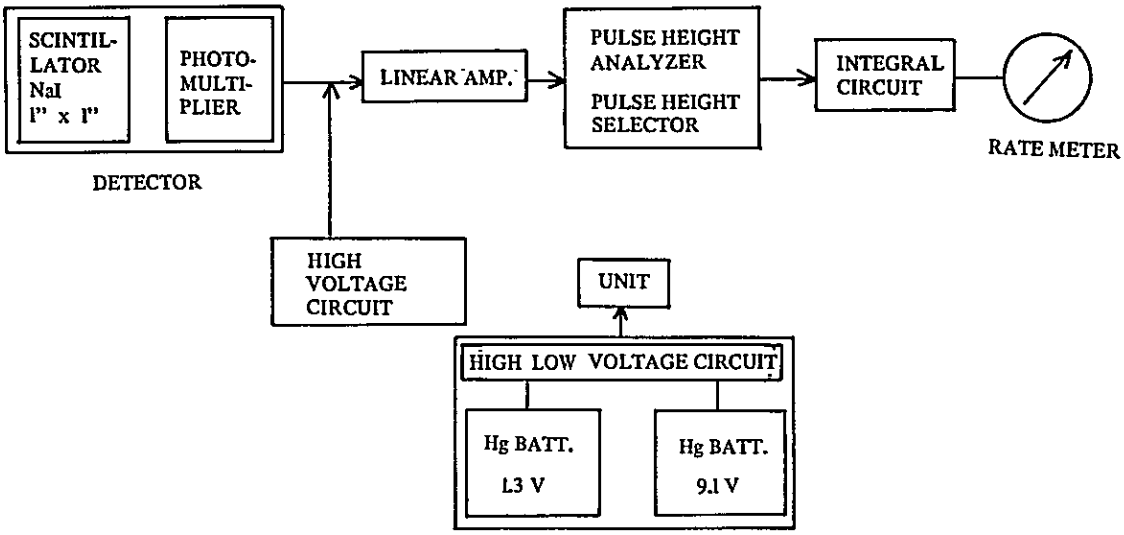


Fig. 4 Block diagram of the Portable Scintillation, Type TCS-122C

(4) Other Instruments

One portable ultraviolet lamp and a paper chromatography equipment were used. The former was used for identifying fluorescent radioactive minerals and the latter for simple analysis of uranium.

2-4 Method of Survey

The equipment used for the survey were two Toyota land cruisers, two land rovers which were rent through the Pakistan Atomic Energy Commission and the radiometric instruments mentioned in the previous section.

The counters were mounted on the two land cruisers and two field parties were organized. A car-borne survey meter was mounted on one vehicle and a man-borne type connected with a recorder on the other. The efficiency of the car-borne type, however, decreased considerably because of the heat and the long drive from Lahore through Rawalpindi, Multan, Karachi, to Trubat in nine days, and it was not possible to use the equipment at the survey area. Thus both parties carried out the survey by mounting man-borne type connected to recorders.

The recorders connected to the radiometric instrument sent chart paper at constant speed, and the vehicle was driven at speeds not exceeding 20 miles per hour, and the radioactivity of all accessible roads were recorded. The localities of the anomalies were entered in the chart records determined by the road marks and the distances indicated by the trip meter of the vehicles.

The locallties are not as accurate as desired as the issued topographic maps were of 1:253,440 (1 inch to 4 miles) scale and the chart speed was not governed by the transmission of the vehicles. The total distance of the travel during the survey was 1945.9 miles, which included 660 miles between Rawalpindi and Multan through Khushab and Dera Ghazi Khan for the visit to the ore deposit and the study of the Siwalik group in the Dera Ghazi Khan district, 366.7 miles between Karachi and Turbat through Bela and Arawan to the survey area, and also for the radiometry of the formations of the same age as the Siwalik group and the total distance of travel within the survey area for the two parties was 919.2 miles.

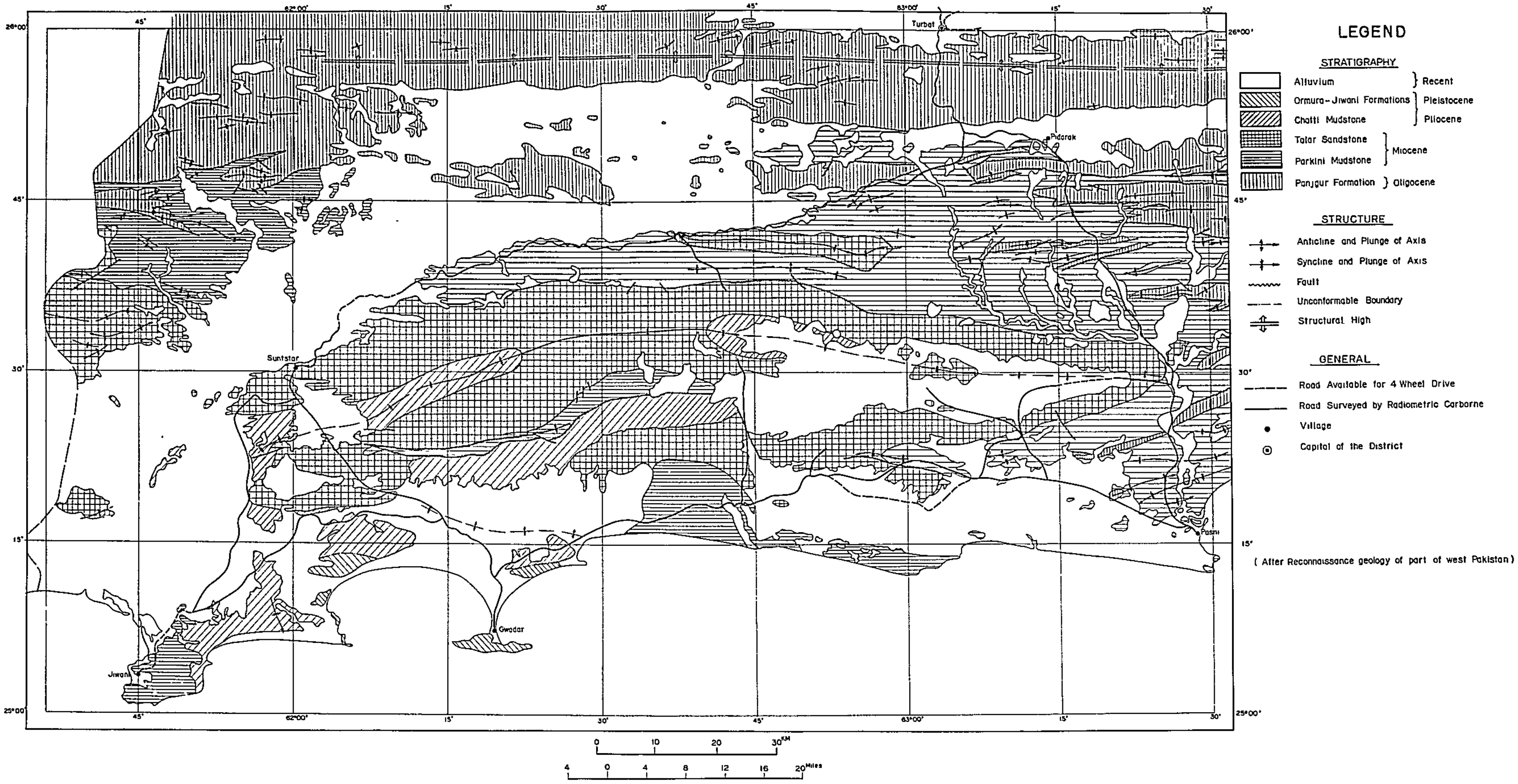
2-5 Geology

The geology of the western part of the Makran Coast consists of the Oligocene, Neogene Tertiary, and Quaternary formations unconformably overlying these strata. The stratigraphy of these formations is laid out in Table 1. There are very few publications concerning the geology of this area, and the "Reconnaissance Geology of Part of West Pakistan" by Hunting Survey Corporation (1961) is the major reference.

Table 1 Generalized section of rocks exposed in the district

Geological Age		Formation	Thickness (feet)
Quaternary	Alluvium	Alluvium	0 - 50
	Pleistocene	Jiwani Formation	100 ±
		Ormara Formation	200 ±
Tertiary	Pliocene	Chatti Mudstone	4,000 ±
	Miocene	Talar Sandstone	10,000 - 15,000
		Parkini Mudstone	4,000 ±
	Oligocene	Panjgur Formation	4,000 ±

Fig. 5 GEOLOGIC MAP OF THE WESTERN DISTRICT OF MAKRAN COAST



Panjgur Formation (Oligocene)

This formation is widely distributed in the northern and eastern parts of the surveyed area and consists of alternation of sandstone and mudstone with the former constituting the major portion. The Sandstone is composed of well sorted fine to medium-grained calcic to dolomitic sediments, the thicknesses of the individual beds range from 1 inch to 5 feet, while those of the mudstone beds are generally 1-2 inches and occassionally reach 50 feet. Fossils have not been found, but it is believed to be of marine origin.

Parkini Mudstone (lower Miocene)

This formation consists mainly of mudstone with indistinct bedding planes. Thin beds of sandstone are intercalated in some parts. The sandstone increases upward and finally grades into the overlying Talar sandstone. Large fossils are not contained in this formation, but many small foraminifer fossils are found from the mudstone, and from the evidences of these fossils, this formation is believed to have been deposited in shallow marine environment. This formation conformably overlies the lower Panjgur formation and the boundary of these two is very clear. Also it is well expressed in the topography due to the difference in resistance to erosion.

Talar Sandstone (upper Miocene)

This formation is composed of sandstone, mudstone, and limestone. The upper and lower hirizons are pelitic and grades into the overlying chatti mudstone and the underlying Parkini sandstone. The sandstone consists of fine to medium-grained sediments and the thicknesses of the individual beds range from several inches to 20 feet and the average is 3-5 feet. The lithology is generally a repetition of regular alternations of sandstone and mudstone, and many cross beddings and ripple marks are observed. The sandstone is generally soft with some calcic and compact parts, but this formation as a whole is strongly resistant to erosion and shows protruded topography. Many bi-valves and gastropod fossiles have been found from this formation, but the occurrence of foraminifer fossils are rare. From the evidence of the fossil shells, this formation is believed to have been formed near river mouths or in shallow sea.

Chatti Mudstone (Pliocene)

This formattion is composed of mudstone and in some parts intercalation of siltstone and sandstone. The sandstone is generally less than 1 foot thick and is composed of fine-grained sediments and it tends to increase downward finally grading into the underlying Talar sandstone. This formation is overlain unconformably by the Ormara formation, but the lithology of these two formations is very similar .and is difficult to distinguish. Fossils of bi-valves, gastropods and foraminifera have been found from this formation and these fossils indicate that it was deposited near river mouths or in shallow sea as in the case the Talar sandstone.

Ormara Formation and Jiwani Formation (upper Pliocene and Pleistocene)

The Ormara formation is composed of loosely consolidated sandy clay and thin beds of sandstone are intercalated in some parts. The Jiwani formation consists of fossiliferous limestone, sandstone and conglomerate. The sandstone consists of well sorted medium to coarse-grained sediments and cross bedding is developed.

The Sedimentary Environment of the Formations of the Same Geologic Age as the Siwalik Group

The uraniferous formation distributed in the vicinity of Dera Ghazi Khan is believed to be a part of the Siwalik group of Miocene - Pliocened age and the Talar sandstone is thought to be approximately of the same geologic age. The Siwalik group consists of the middle Miocene to early Pleistocene formations and is distributed from Potwar plateau (Salt Range) to India, and it is considered to be of continental deposition by the occurrence of mammalian fossils from each horizon. The group distributed near the uranium deposit to the west of Dera Ghazi Khan consists mainly of medium to coarse-grained arkosic sandstone and in some parts conglomerate, fine-grained sandstone and mudstone is intercalated. They are non-marine formations deposited in the fore basin of geosyncline. The Talar sandstone distributed in the surveyed area was deposited in approximately the same period as the Siwalik group, but the sedimentary basin is different and it is believed to be made of shallow sea sediments from the evidence of the fossils contained. This is the major difference between the two formations.

2-6 The Distribution of Radioactivity

The exposure of rocks in the area is excellent except in deserts and in the flat areas of the platforms. Most of the roads passable by four-wheel drive vehicles run more or less parallel to the strike of the geologic formations (east-west) or in the deserts, and those intersecting the strike direction at right angle are very rare.

In areas of gentle hills, the distance between the roads and the outcrops were often fairly far. However, the rocks were ocassionally exposed even in the flat areas of the platform and it was observed that the overburden of the weathered products were thin with the exception of the deserts in the coastal areas.

Figure 6 shows the outline of the distribution of radioactivity, it admittedly is a brief outline, but is useful as a measure of the approximate distribution. The measured values cannot be evaluated mechanically because of the differences in the distance of the vehicle and the outcrops, the conditions of the outcrops, the kind of rocks and other factors. The radioactivity is classified into the following three groups for convenience; 0 - 2,999 cpm, 3,000 - 5,999 cpm, 6,000 - 8,999 cpm. The natural count was 3,500 - 4,000 cpm.

The differences of the sensitivity of the instruments was calibrated to the values of the man-borne survey meter by measuring the radioactivity of the same road by various instruments. During the present survey, the efficiency of the car-borne meter decreased because of the high temperature and the effect of the vibration during the transport, and thus most of the record is that obtained by connecting the man-borne meter to the recorder of the car-borne equipment.

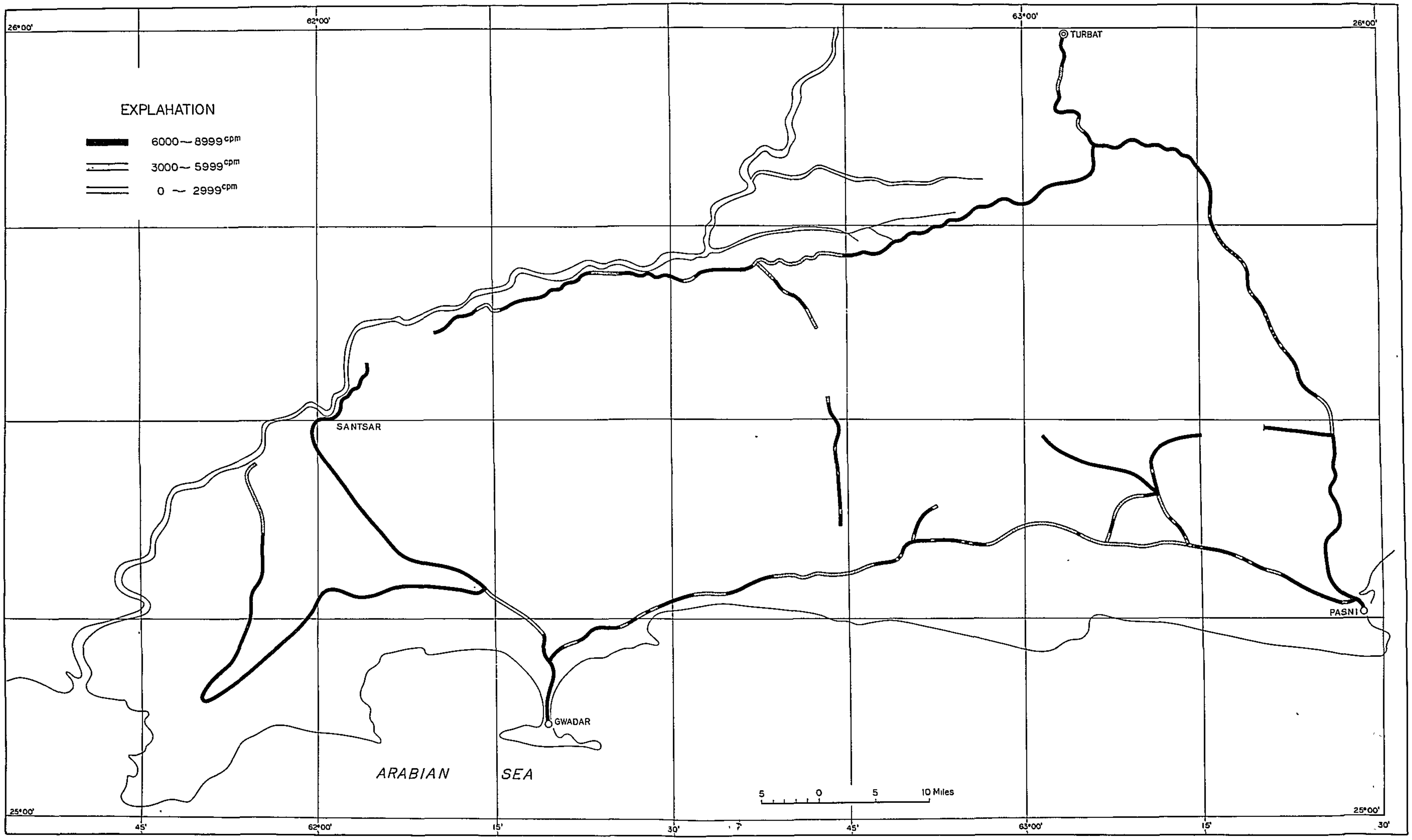
The radioactivity measured directly at the outcrops by portable scintillation counters are listed in Table 2.

Table 2 Radioactivity of Rocks

Horizon	Lithology	Radioactivity	Remarks
River bed	sediments	15 - 18 $^{\mu r}/h$	Natural Count 8 - 12 $^{\mu r}/h$
Desert	sediments	15 - 17 $^{\mu r}/h$	
Talar Sandstone	Sandstone	13 - 14 $^{\mu r}/h$	
	Mudstone	15 $^{\mu r}/h$	
	Sandy mudstone	12 - 13 $^{\mu r}/h$	
	Alternation s.s & m. s.	15 $^{\mu r}/h$	
Parkini Mudstone	Mudstone	18 - 20 $^{\mu r}/h$	
	Sandstone	15 $^{\mu r}/h$	

Fig. 6

DISTRIBUTION MAP OF RADIOACTIVITY IN THE WESTERN DISTRICT OF MAKRAN COAST



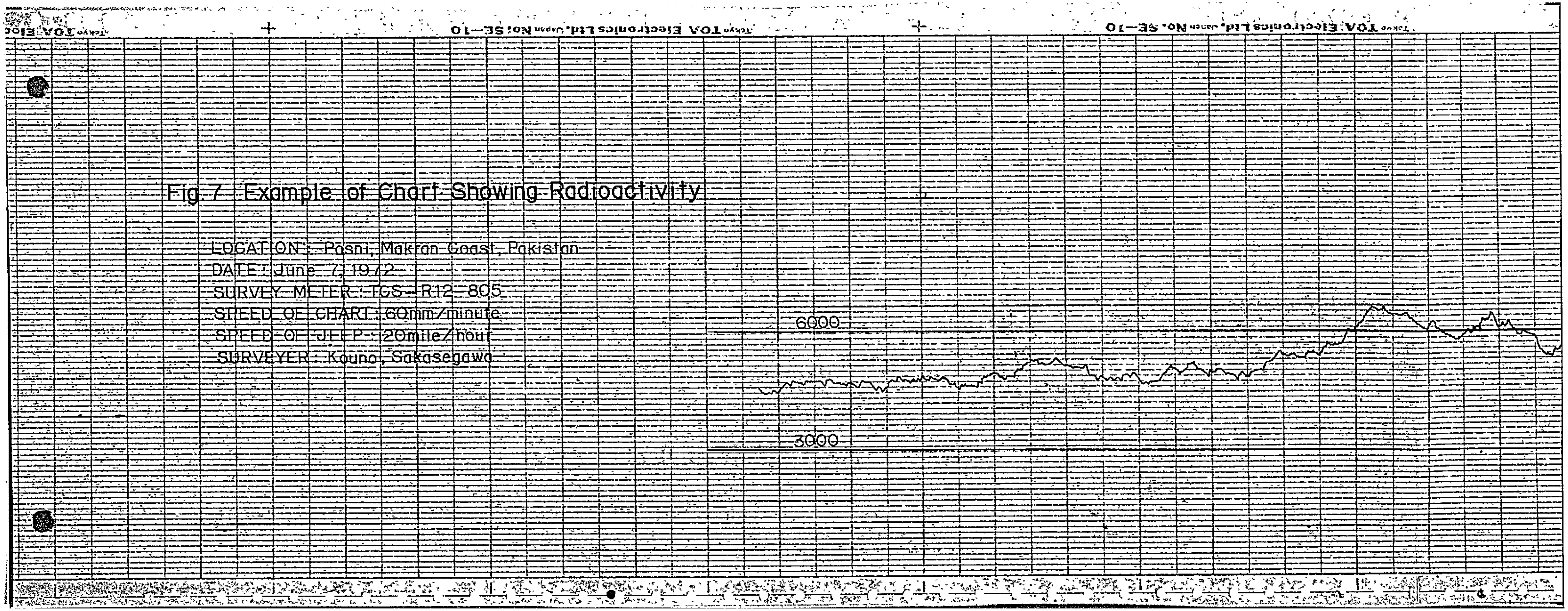
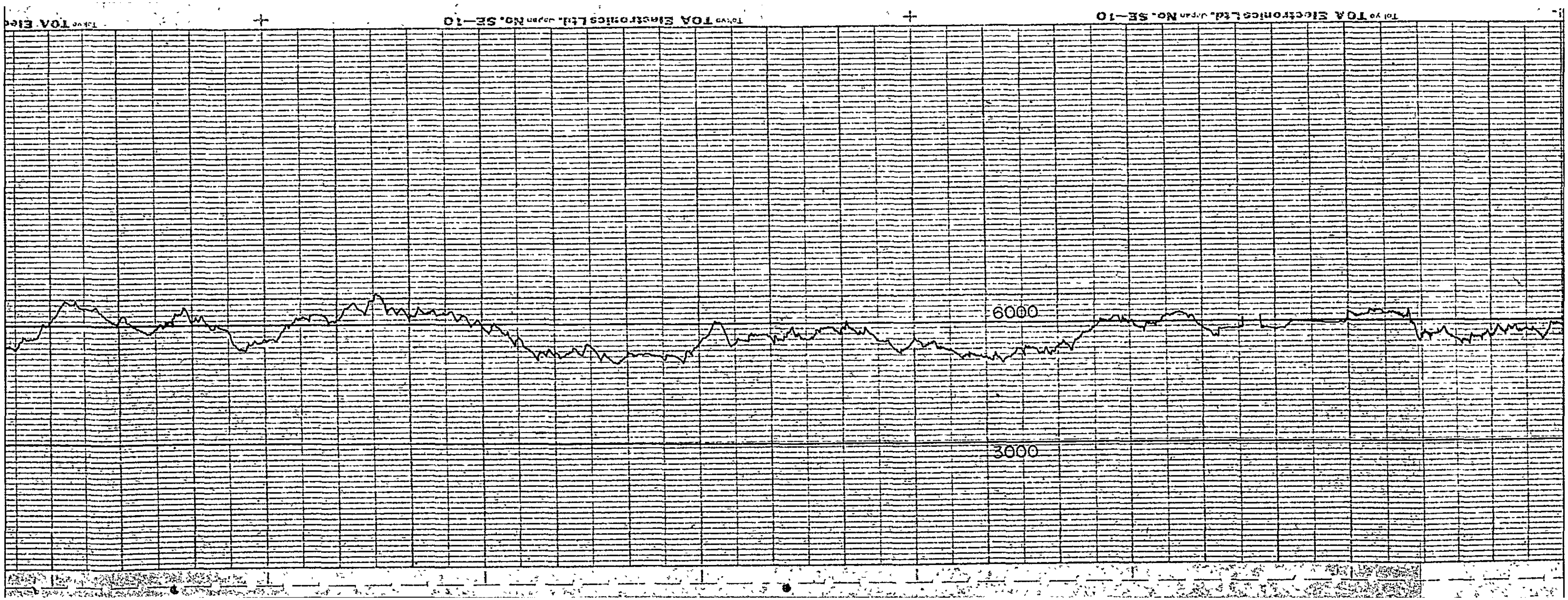


Fig. 7 Example of Chart Showing Radioactivity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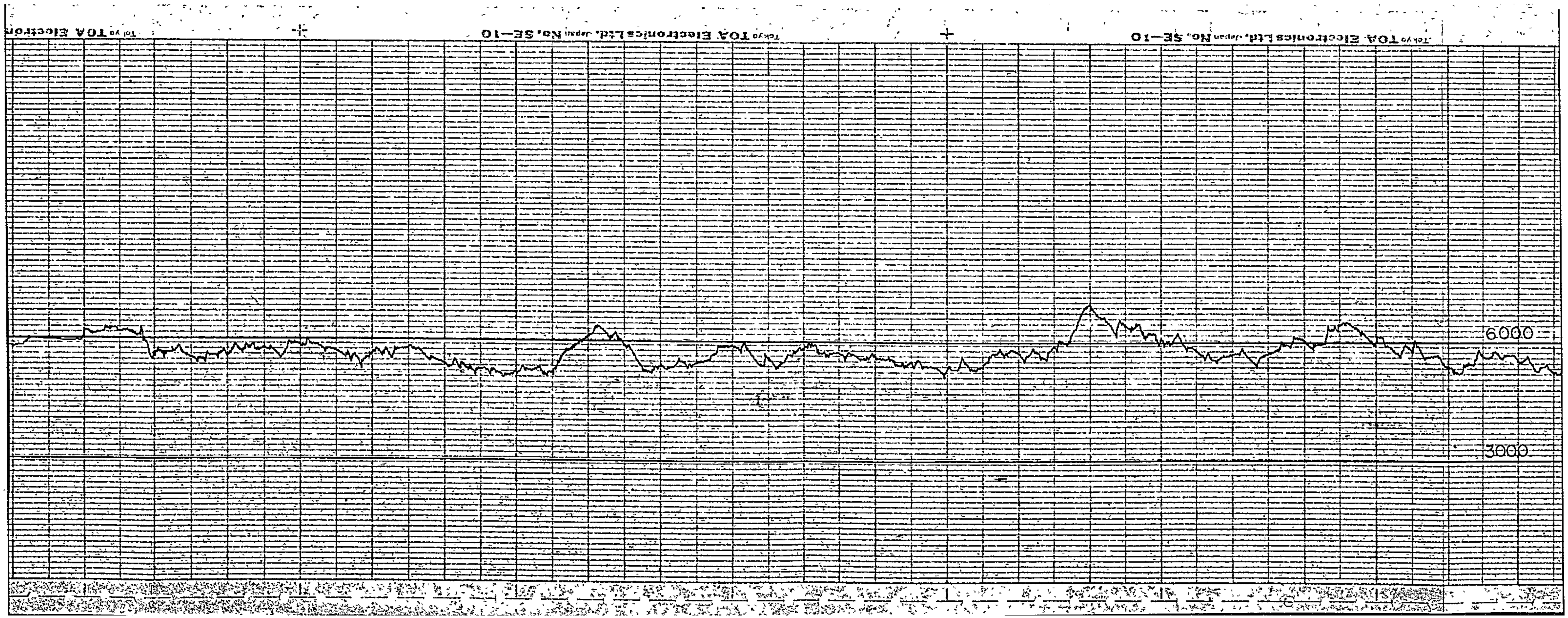
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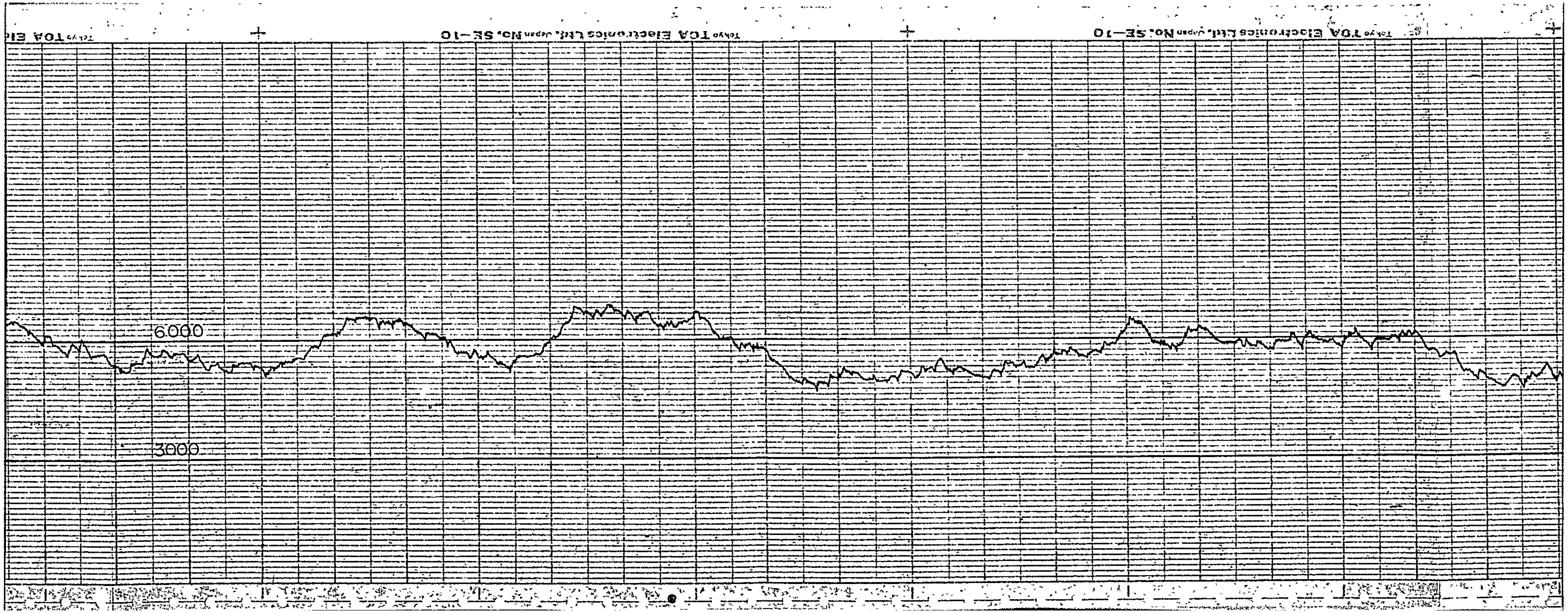
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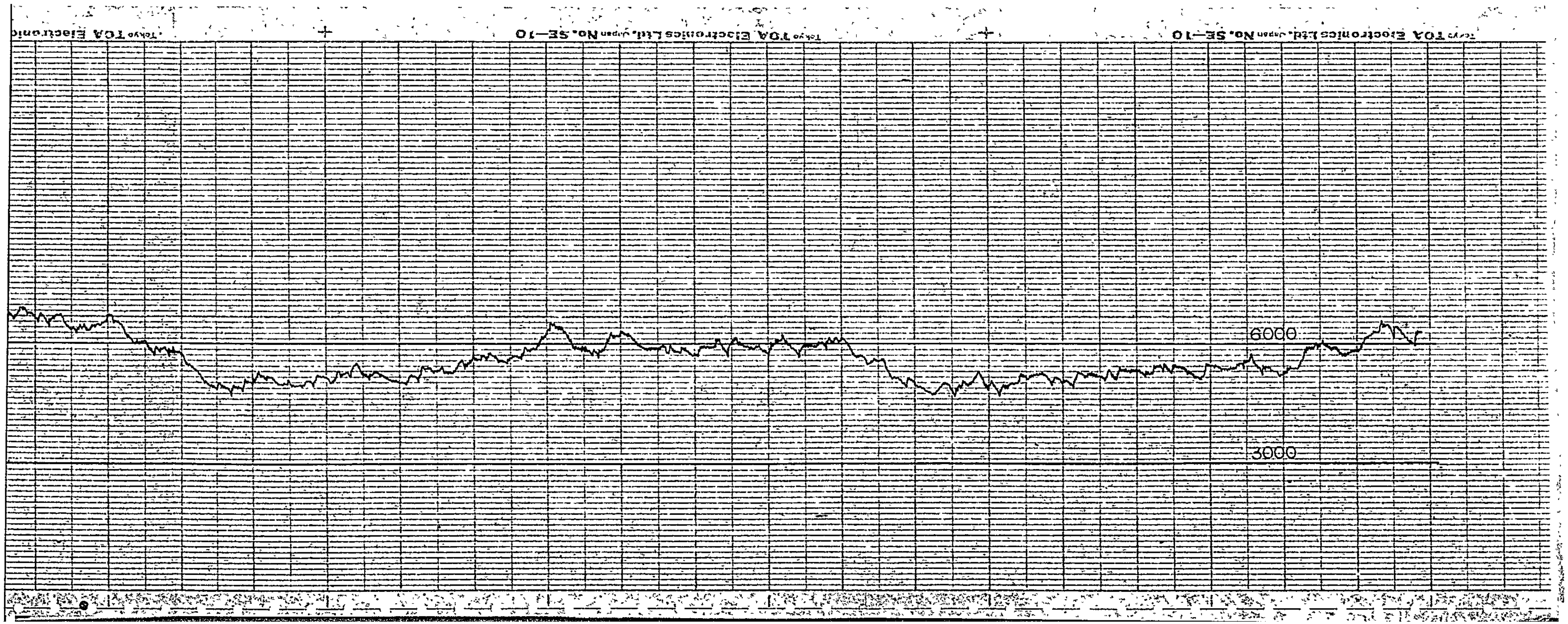
6000
3000

The Parkini mudstone formation underling the Talar sandstone which is believed to be of the same geologic age as the Siwalik group generally showed somewhat higher radioactivity than the latter strata. In the Talar sandstone, the higher radioactivities were measured in mudstone portions with finer grain size than in the sandstone parts.

The natural counts of the two man-borne survey meters were in the range of 3, 500 - 4, 000 cpm and most of the measured values were in the order of 6, 000 cpm, and values higher than 9, 000 cpm were not recorded. The formations, river-bed sediments, desert sediments did not show conspicuous anomalies and the values were in the range of 2, 000 - 8, 000 cpm.

3. CONCLUSION

The results of the survey and the recommendations concerning the future prospecting for uranium are as follows.

(1) The present survey was carried out for various reasons in the hottest time of the year (April - September) and the outdoor temperature at times exceeded 50° C and together with the few roads passable by four-wheel drive vehicles, the efficiency of the car-borne radiometry was greatly hampered. Thus it was not possible to carry out survey of the scope and density as originally planned.

(2) As the traverse density is very low at about 90 line metres per square kilometre, it was not possible to investigate the occurrence of uranium concentration conclusively by this survey alone.

(3) The fact that the Talar sandstone which is correlated to the Wiwalik group and the Parkini mudstone which directly underlies the Talar sandstone showed somewhat higher radioactivity than other units indicates the possiblity that radioactive anomalies may be found by detailed survey of the area.

(4) Most of the sedimentary uranium deposits in the world known to date occure in coarse-grained non-marine formations while the Talar sandstone and the Parkini mudstone are composed of fine-grained sediments deposited at river mouths or in shallow seas.

(5) If radiometric survey is to be carried out in this area in the near future, the following should be noted.

i) Carry out field work during the winter months (November - February) in order to work efficiently.

ii) The density of the radiometric survey in case of car-borne method in Japan is about 1,000 - 1,400 line metres per square kilometre because of the dense network of roads and the complicated geologic structure. In this general area, however, where the geologic structure is much simpler and the exposure of rocks very good, reconnaissance radiometric survey can be attained by about 300 - 500 line metres per square kilometre. In the present surveyed area, this can be done by man-borne methods.

iii) The survey method recommended is, as the air-borne and car-borne methods will not yield any more information concerning the distribution of radioactive elements, systematic survey using man-borne and portable scintillation counters. If radioactive anomalies are detected by this reconnaissance, detailed survey using trecnhing and drilling is desireable.

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