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Potential for the Occurrence of Thick Lignite Deposits in the Thar Desert and Adjacent Lower Indus Plain, Sindh Province, Pakistan

by

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CONTENTS

CONTENTS (cont'd)

ILLUSTRATIONS

CONTENTS (cont'd)

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ABSTRACT

The Thar Desert is a very arid, dune-dominated area of some 200,000 km^2, approximately 25% of which is in Pakistan. The desert lies in a structural depression between the fold and thrust belt of central Pakistan and the outcropping Precambrian shield and Tertiary Deccan flood basalts of India. Geologic projections of known coal-bearing rocks from Sindh Province, Pakistan, and western India, plus information obtained from water-well drilling in western Thar, suggest that the Thar Desert and lower Indus plain areas of Pakistan are underlain by extensive lower Tertiary coal deposits.

Two- to three-meter-thick subbituminous coal beds are being mined from depths of 30 to 100 meters in Sindh; lignite beds up to 10 meters thick are being strip mined in Kutch District, India; and "peaty" looking lignite beds 4 to 18 meters thick are being mined from depths of 40 to 87 meters in Rajasthan State, India, where a single coal bed 72 meters thick has been recorded in one drill hole.

Geophysical logging of two water wells drilled in the Thar Parkar District of Pakistan, plus physical testing of "peaty" looking material cored from a third hole, including proximate and ultimate analysis, reflectance, maceral analysis, nuclear magnetic resonance, and palynology, indicate that Paleocene to Eocene lignitic to subbituminous coal beds 8 to 17 meters thick were intercepted at depths of 165 to 245 meters. Although these coal beds cannot be precisely correlated to the coal beds of Sindh or western India, they are by far the thickest recorded in Pakistan, and probably extend through most of Thar and the lower Indus plain.

At some places in the Thar Desert and the Indus plain, the thickness of alluvial or aeolian cover can exceed 100 meters. In order to locate shallow bedrock before drilling, a coal exploration program in these areas would ideally begin with inventorying existing water-well and petroleum prospecting data, and conducting ground geophysical surveys. The difficulty in obtaining such data, and the magnitude and importance of this discovery, however, suggest that an exploratory drilling program of about six boreholes should begin immediately.

INTRODUCTION

Since 1985, the United States Geological Survey (USGS) and the Geological Survey of Pakistan (GSP) have been conducting a coal resource exploration and assessment program in Pakistan (COALREAP), under the auspices of the United States Agency for International Development (USAID) and the Government of Pakistan (GOP). The primary focus of the program to date has been the exploration of specific coal fields, and regional geological studies in the provinces of Sindh, Balochistan, and Punjab. The focus of the exploratory program has been directed toward expanding the boundaries of the existing coal fields, and all the discoveries of new coal-bearing areas have occurred along the peripheries of known coal deposits. This paper discusses possible occurrences of lignite in a large area of Sindh Province which has not yet been explored for coal. Based on geologic projections from known coal fields, and reports of coal intercepted by other agencies while drilling for water and petroleum, this area can reasonably be expected to be coal-bearing.

Purpose and Scope

The purpose of this paper is to stimulate interest in coal exploration in the Thar Desert area of Pakistan. In order to alert the reader to the potential logistical difficulties that might be encountered in exploration or development of this remote area, the paper begins with a brief discussion of the regional geography . Because very little is known about the geology of the study area, this paper synthesizes geologic information from surrounding areas, which can be projected into the study area. The geologic synthesis of surrounding areas is somewhat detailed in order to provide a comprehensive backround for potential readers in Pakistan, where information on the coal fields of India is not readily available. The paper then discusses findings of COALREAP investigations of water wells drilled in the study area by other agencies. This section of the paper is also rather detailed, in order to prevent the prevailing opinion that carbonaceous material encountered in these wells is modern Indus peat, from deterring exploration for coal. Our findings indicate that several water wells drilled in the Thar Desert area of Pakistan have intercepted lignite of probably early Tertiary age. The paper concludes with specific recommendations for a coal exploration program of the area.

Acknowledgements

In addition to the authors, a number of other COALREAP participants from USGS, GSP and USAID contributed directly or indirectly to this report. In particular, the authors wish to thank Peter Warwick of USGS, who provided the initial USGS contact with representatives of the British Overseas Development Agency (ODA), that alerted the authors to the direct evidence for what previously had been geologic speculation on the occurrence of coal in Thar. The authors also want to thank A.H. Kazmi, Director General, GSP, for providing field support for this project and Sindh COALREAP in general. The ability of USAID drivers Imdad Janjua and M. Niaz Janjua was also critical to completing field work in Thar.

Completion of this effort would have been impossible without the information and assistance provided by other agencies working in Sindh. In particular, the geologic information, logistical support, and permission to log wells provided by Mr. Abdul Khalique Shaikh, chief hydrologist, and Mr. Gulsher Mangi, geologist, of the Sindh Arid Zone Development Authority (SAZDA), were critical to the project. The information, assistance, and rock samples provided by the Mott MacDonald Group/Groundwater Development Consultants International Ltd., Hyderabad, in particular geologist David Izatt, and the permission to release the data by regional director R.P. Birch, were greatly appreciated.

The following scientists at the USGS headquarters in Reston Virginia provided analytical support: low temperature ashing, Jim Pontolillo; x-ray diffraction (ash), Frank Dulong; reflectance and maceral analysis, Ron Stanton; nuclear magnetic resonance, Pat Hatcher; fossil pollen identification, Norm Frederiksen. Proximate and ultimate analysis were performed by Dickenson Laboratories, El Paso Texas, under contract to USGS.

GEOGRAPHICAL SETTING

The Thar Desert, also known as the Great Indian Desert, covers approximately 200,000 km^2 in southern Pakistan and northwestern India (fig.1). About 25 percent of this is in Pakistan, in the Provinces of Sindh and Punjab. Most of the Indian portion is in the State of Rajasthan. The desert is bordered by the irrigated Indus plain to the west, the salt marshes of the Rann of Kutch to the south, the Aravalli mountain range to the southeast, and the Punjab plains to the north. The

Figure 1. Location map, Thar Desert area and vicinity.

area is characterized by aeolian sand dunes up to 150 m high, that are active to semi-stabilized by scrub vegetation. Many areas are covered by semi-stabilized longitudinal dunes typically about 20 m in height, with smaller active barchan dunes or playas in interdune areas. In the northern part of the desert, these are sometimes developed into northeast - southwest trending seifs which are typically about 25 km long. Some areas contain very large and barren active barchan or transverse dune fields. Towards the west of the Indian side of the desert, the dune fields give way to sandy plains, with scattered sand hills locally called "bhits". Annual rainfall varies from less than 10 cm in west Thar to 50 cm in the east, and generally is about 20 cm in the Pakistani portion. Drainage in the desert is internal. Much of the lower Indus plain is equally arid, and if not for extensive irrigation would be considered desert from the standpoint of rainfall. Most of the rainfall occurs during the July to September monsoons from the southwest; prevailing winds are from the northeast during the rest of the year. From May to June dust storms with winds of 140 to 150 km/hr are common in the desert.

In Pakistan, the Thar Desert is sparsely populated by small agricultural communities of mixed Moslem and Hindu origin. There are no paved roads in the Pakistan portion of the Thar Desert, and travel is by well-marked but very sandy roads where 4 wheel drive is absolutely required. Local populations usually travel by surplus heavy military vehicles converted to buses. Access to the desert border from the heavily populated Indus Plain is available by numerous paved roads. The Karachi-Hyderabad-Mirpur

Khas railroad crosses the desert via Jodhpur (fig. 1).

GEOLOGICAL SETTING

The Thar desert and the lower Indus plain are set in a depression bounded on the east by the shield rocks and flood basalts of peninsular India, and on the west by the fold- and thrust-belt mountains formed by the collision of the Eurasian and Indo-Australian plates. Alluvium of the Indus plain is typically about 100 m thick and mostly of Recent age.

Most of the surface of the Thar desert is covered with recent dune sand. The origin of the dune sand may be either transport from the Rann of Kutch or the Indus plain by monsoon winds, or, by the reworking of local alluvial deposits by wind (see Gupta and Prakash, 1975). Below the dune sand are presumably alluvial deposits of the Indus river system. Bedrock outcrops in the Thar desert are confined to the east-central part of the the Indian side, and one small inlier of the Indian shield at Nagar Parkar on the southern end of the Pakistani side.

Figure 2 is a map of general geology of Pakistan and west-central India, south of the Himalayan front. The large Mesozoic outlier in south central Thar is known by the Indian geologists as the "Jaisalmer Jurassics", which outcrop on the Mari-Jaisalmer structural arch. This appears to be part of the Jacobabad basement high which extends into Pakistan. The Mesozoic - Cenozoic outlier in Kutch appears to be a similar structure that dips away from the Indian shield outcrop at Nagar Parkar, perhaps displaced from most of Thar by the Kutch fault zone. The Indus plain is bounded on the west by the fold and thrust mountains of

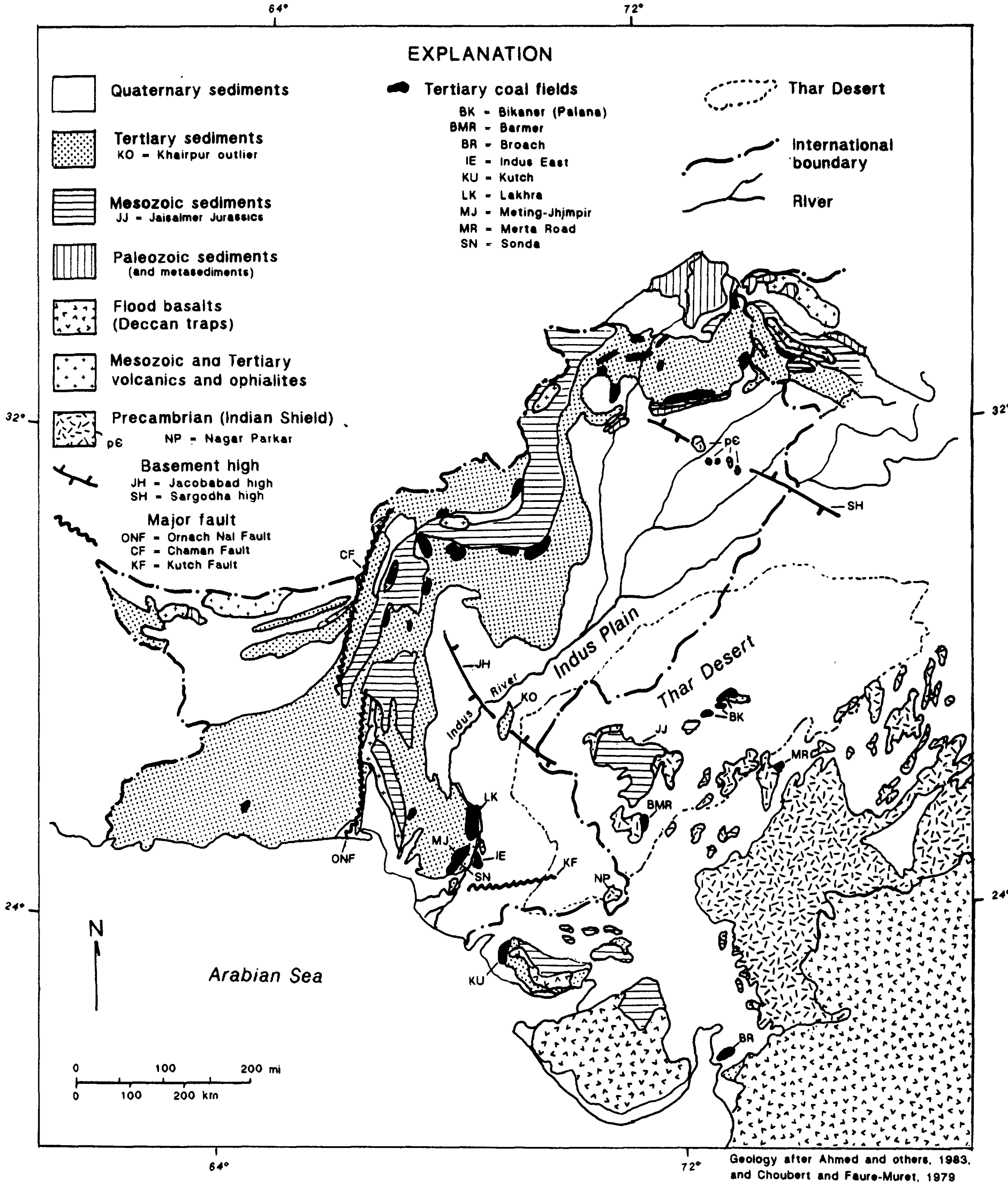


Figure 2. General geology and location of Tertiary coal fields, Pakistan and west-central India, south of the Himalayan front.

the collision zone, and on the north by the Himalayan thrust. Bedrock exposures in the Indus plain are limited to Eocene rocks exposed in the Khairpur outlier along the Jacobabad high, just west of the Jaisalmer Jurassics, and the Precambrian shield inliers of the Kirana Hills along the Sargodha high. As far as is known, the stratigraphy of Thar is more or less similar to the known stratigraphy of Sindh, and until very recently, the stratigraphic nomenclature of Sindh has been in general use for Thar. The lower Indus sedimentary basin of Sindh consists of about 9000 m of Jurassic through middle-Miocene shallow shelf and paralic pre-collision sediments, and 3000 m of middle-Miocene to Recent post-collisional molasse deposits. The relevant stratigraphy of Sindh has been covered in detail in previous COALREAP reports (e.g. SanFilipo and others, 1988), and will be discussed only briefly here.

The geology of the lower Indus Basin and Thar have come under increasing scrutiny as oil and gas prospects in recent years, and most of the area is under concession or prospecting license. A number of test and producing wells have been drilled, and the area is well covered with seismic lines, but most of this information is not currently available to GSP.

KNOWN COAL OCCURRENCES OF THAR, THE LOWER INDUS PLAIN, AND ADJACENT AREAS

Introduction

The location of Tertiary coal fields of Pakistan and western India, south of the Himalayan front, are shown in fig. 2. All the known occurrences of lignite in Thar are in the subsurface, but near the bedrock exposures on the Indian side. The discovery of these coal fields, however, appears to be more related to population distribution than to geologic inference from the outcrops. The bedrock areas are generally more populated than the dune fields, and in most cases, coal was first discovered by water-well drilling near villages. Areas where coal was noted were then further investigated by government-sponsored exploratory drilling. Outcrops of coal were noted as early as 1872 (Wynne and Fedden) in the Kutch area, just south of Thar.

The confirmed coal occurrences in the lower Indus plain are confined to the Indus East (a.k.a. Sonda East) coal field (fig. 2) recently discovered by COALREAP drilling (SanFilipo and others, 1988). By examining the pattern of known Tertiary coal fields in figure 2, it is clear that the potential for subsurface coal occurrence can be projected from known coal fields in Pakistan and western India up or down dip to almost anywhere in the Indus basin (e.g. wherever Tertiary rocks are present between the Chaman/Ornach Nal fault system and the Indian shield). The problem therefore becomes one of determining where Lower Tertiary rocks could be close enough to the surface to warrant exploration for coal, yet have not been removed by modern Indus erosion.

The known coal fields of Pakistan have been examined in detail in Ahmed and others (1986) and other COALREAP reports (Schweinfurth and Hussain, 1988, Landis and others, 1988, Warwick and Hussain, in press), and will be discussed only briefly for comparative purposes here. The remainder of the report will discuss the coal fields of western India that can be projected towards Pakistan, and the results of water well investigations done for this report.

Coal fields of Sindh Province, Pakistan

Coal in Sindh Province occurs in the Paleocene Bara Formation and the Eocene(?) Sohnari Member of the Laki Formation. Both were deposited in sandy coastal plain environments. At least eight coal zones have been identified in the Bara Formation. Bara coal beds typically 2 to 3 meters thick are mined from depths of 30 - 100 meters in the Lakhra coal field (fig. 2). A single bed 6 m thick was recorded at a depth of 180 m in a drill hole in the Sonda coal field (fig. 2), but no mining has occurred there to date. Sohnari coal occurs in a single zone of one or two beds; each of which is rarely over one meter thick, and usually considerably thinner. They are mined from depths of about 20 - 30 m in the Meting-Jhimpir coal field (fig 2).

Bara and Sohnari coal of comparable thickness and depth to the other coal fields of Sindh has been recorded in exploratory holes drilled in the Indus East coal field (fig. 2). The Indus East field is a continuation of the Sonda coal field below the alluvial cover on the opposite side of the Indus River. The existence of the field was predicted by GSP and USGS from 1) updip projections from the Sonda field 2) isolated bedrock exposures near Jherruck, and 3) oil and gas drilling in the Indus plain (GSP and USGS, 1985). Similar projections to the shield areas of India are the basis for the coal potential assigned to the remaining lower Indus plain and Thar desert.

The coal of Sindh is typically subbituminous C in rank, and is dark brown to black, generally dull or slightly banded by previtrain, and contains abundant visible resin and pyrite. It is generally hard and brittle to waxy when fresh, but crumbles easily after prolonged exposure.

Coal fields of Punjab and Balochistan Provinces, Pakistan

Coal from the Paleocene Hangu and Patala Formations is mined from several coal fields in Punjab. The coal is typically high volatile C to B bituminous; the higher rank relative to the coal of Sindh can probably be attributed to regional tectonic forces. Coal occurrences in the Jurassic and Permian have also been noted in Punjab (Ahmed and others, 1986).

Bituminous coal in Balochistan is mined from the Eocene Gazij Formation at several coal fields. The environment of deposition of the Gazij coals appears to have been a mud dominated system significantly different from that of Sindh.

Projections of coal occurrence from the coal fields of Balochistan and Punjab to the Indus Plain and Thar desert are less certain than those from Sindh due to the greater distance to the coal fields of India and increasing structural complexity. The Karana hills, which are small outcrops of Indian shield lying on the Sargohda basement high between the coal fields of Punjab and the Thar desert, demonstrate the increasing structural complexity of the Indus plain going to the north.

Coal fields of Gujarat State, India

Coal has been sporadically mined in the Kutch District of Gujarat since before the Wynne survey of 1867-1869 (Wynne and Fedden, 1872). The coal occurrences reported by Wynne and Fedden were all thin lenticular beds assigned to the Upper Jurassic, but which may actually be Lower Cretaceous based on more recent work (Biswas, 1971; Anand-Prakash, 1985). Wynne noted a "few thin carbonaceous layers of shale...in the Tertiary...none of them promising."

Today the Mesozoic coals have no economic significance, but the Tertiary coals are being mined from several fields in the northwest part of Kutch (fig. 2). The largest of these, the Panandhro field, has been strip mined since 1982(?). Several lignite beds up to 10 meters thick occurring between 8 and 58 meters depth are reported (Gowrisankaran and others, 1987) from Eocene rocks which are generally thought to be equivalent to the Laki Formation of Sindh. Biswas (1965) proposed revised nomenclature for the Tertiary of Kutch, but the nomenclature of Sindh is preferred by many workers. A comparison of the stratigraphic nomenclature of Sindh with the revisions of Biswas is shown in figure 3.

The most obvious differences between the Tertiary systems of Sindh and Kutch are the much greater total thickness in Sindh, and several unconformities in Kutch that are not recognized in Sindh. The thicker section in Sindh can be attributed to on-lap thinning over basement or Deccan traps towards the east.

Correlations between the coal-bearing intervals of Sindh and Kutch as shown in figure 3 are dubious. The thickest coal beds in Kutch are generally thought to be basal Laki (Sohnari Member) equivalents, which are relatively thin in Sindh, while the thin Paleocene coal beds of Kutch are thought to be middle Ranikot (Bara Fm) equivalents, which are thick in Sindh. The Laki age assigned to the Naredi Formation is based mostly on the presence of Assilina granulosa, which occur near the middle of the

SERIES	SIND (after Shah, 1977)	KUTCH (after Biswas & Raju, 1971, 1973; Biswas, 1971)	LITHOLOGY
Recent			
Pleistocene	Lei Conglomerate (450 m)	Miliolite Fm (16m)	Kutch: pelletoidal ss, oomicrite Sind: sandy pebble cglm
Pliocene	Siwalik Gp/Manchar Fm (1000 m)	Sandhan Fm (300 m)	sandstone, conglomerate Kutch: oyster beds
Miocene	Gaj Fm (650 m)	Vinjhan Sh (130 m)	claystone and marl
		Khari Nadi Fm (70 m)	variegated siltstone
Oligocene	Nari Fm (1400 m)	Maniyara Fort Fm (28 m)	marly limestone Kutch: abdt glauconite Sind: top sandstone
Eocene	Kirthar Fm (1200 m)	Fulra Limestone (14 m)	massive fossiliferous limestone
		Harudi Fm (23 m)	marlstone
	Laki Fm (600 m)	Naredi Fm (40 m)	Kutch: glauconitic, fossiliferous marl, bs gyp + lignite beds Sind: foss ls, marl, bs ss + laterite + few thin coal beds
Paleocene	Ranikot Gp (1200 m)	Matanomadh Fm (50 m)	Kutch: vrgt volcani-clastics, lat, bent, tuff slst/ss (Deccan), few thin lignite beds Sind: ss, clst, coqna, mult coal zones middle
Upper Cretaceous	Deccan Traps (25 m)	Deccan Traps (610 m)	amygdaloidal basalt

Figure 3. Cenozoic rock-stratigraphic classification of Sind Province, Pakistan and the Kutch area of India.

formation, well above the coal (Biswas, 1965). The contact between the Naredi and Matanomadh Formations is largely based on a color change which supposedly marks a transition from volcaniclastic to paralic sedimentation, but which may in fact be somewhat arbitrary. Wynne and Fedden (1872, p. 76) believed the contact was conformable and assigned a Paleocene age to both their "sub-Nummulitic" (Matanomadh) and "A" (basal Naredi) beds. Based on faunal evidence, Tandon (1971) and Mohan (1982) also placed the base of the Naredi Formation in the Paleocene. It is possible that the coal-bearing lower Naredi Formation is actually correlative with the Paleocene upper Bara Formation. On the other hand, Frederikson (1989) suggests the Sohnari beds may also be of Paleocene age, based on palynomorphs. Additional work is clearly required to correlate the coal beds of Kutch with those of Sindh.

Several beds of lignite from 3 to 8 m thick were discovered by oil and gas drilling in the Broach District of Gujarat (Venkatappaya, 1971), about 400 km south of Kutch (fig. 2). At the Jhagadia field of Broach, 700 tons per day are being mined from a 5 m bed which lies at depths of about 25 to 150 m, in the Upper Eocene Tarakeshwar Formation. (Gowrisankazzan and others, 1987).

The Mesozoic and Cenozoic sedimentary rocks of Kutch generally dip gently to the south from the basement high at Nagar Parkar. Updip projections to southern Thar from Kutch are somewhat complicated by the active Kutch fault zone (fig. 2).

Coal fields of Rajasthan State, India

Coal was discovered in 1896 in a water well drilled at

Palana, near Bikaner (fig 2). Underground mining began in 1898 and closed in 1966 due to a mine fire (Gowrisankaran and others, 1987). Between 1950 and 1967, 482 boreholes were drilled on the lease, and as of 1987, a surface mine was being planned. Gowriskaran reports a single lignite bed of 4 to 18 m thickness, occurring at depths of 40 to 87 m, in the Laki Formation at Palana.

The lignite at Palana is described as "brown to brownish grey colour resembling that of peat...very light [with] marcasite and stringers of resin in...it." (Dutta, 1971, p.427); "woody to peaty material, disintegrating rapidly on exposure" (Brown and Dey, 1975, p.111). Dutta noted that typical as-received moisture was 45 percent, drying to 17 percent in a matter of days. Because of the way moisture is reported in Indian coals, it is difficult to assign a rank using the moist, mineral-matter free (MMF) BTU method according to the standards of the American Society for Testing and Materials (ASTM), which are generally used in North America. The values reported for coal of Palana, (as well as Kutch) from sources such as Brown and Dey, 1975 (p.74-75) and Bhowmick and Roychaudhuri (1982), show wide variation, but seem to range from the lignite B (soft brown coal) to subbituminous A range, using European low-rank coal classification systems based on parameters such as percent volatile matter and carbon.

Despite numerous revisions based on surface work, the stratigraphic nomenclature of Sindh is apparently retained for the Tertiary rocks of Rajasthan by most geologists working in the subsurface. Analogously to Kutch, most workers consider the Rajasthan coal to be of Laki age, but there is a signifcant body of evidence suggesting a Paleocene (Ranikot) age instead.

Narayanan (1964) proposed the name Palana Formation for the Paleocene - lower Eocene series of Bikaner. Singh (1971) recognized a Paleocene/Eocene unconformity based on megafauna and introduced the Koloyat "stage" for the early Eocene (Laki equivalents), while retaining Palana Formation for the Paleocene. Entirely different nomenclature was introduced by Narayanan (1964) for the lower Tertiary rocks of the Jaisalmer basin which outcrop about 250 km west of Palana. The Bandah Formation was proposed for the middle Eocene (Kirthar Fm equivalents) and the Khuiala Formation was proposed for the lower Eocene (Laki equivalents) and Paleocene (Ranikot equivalents). Das Gupta (1975) introduced the Sanu Formation for the Ranikot equivalents, while retaining the Khuiala Formation for lower Eocene Laki and upper Paleocene Dungan Formation (Balochistan) equivalents.

As a result of detailed biostratigraphic studies for oil and gas exploration, the coal-bearing rocks of the Sanu Formation can probably be assigned to the Paleocene. Singh (1976) for example, has determined that the top of the Ranikot (Sanu) Formation in India is not younger than the P4 planktonic foram biochronozone (Thanetian). Based on their stratigraphic position near the base of the formation (Shrivastava, 1971), the Palana Formation coal beds are probably also of Paleocene age. Early workers established an Eocene age based on palynological work, but "views differ about the possible age of these lignites" (Shrivastava, 1971). Sah and Kar (1974) recorded a diversified palynological assemblage from the Palana Formation which closely resembled that of the (Eocene) Naredi Formation of Kutch. As already discussed, however, there are problems in dating the Naredi Formation. Singh (1974) also collected a palynological assemblage from the Palana lignites which resembled the Naredi assemblages, but he assigned them a Paleocene age.

The Palana Formation consists of sandstone, claystone, "laterite", and lignite (Kholsa, 1973) and can be inferred from Shrivastava to be at least 100 meters thick. It is reported to be directly underlain by the Upper Protorozoic to Cambrian Jodhpur (Vindhyan) Formation at Palana.

Several other coal fields in the Bikaner district (all within 75 km of Palana) have been identified by Government of Rajasthan drilling programs. At Gurka there is a zone of lignite with a typical cumulative coal thickness of up to 27 m, and a single bed of 72 m recorded in one drill hole (Gowriskaran and others, 1987). A 41 m coal bed has been reported from Barsingsar in the Bikaner district. Other Tertiary coal fields of Rajasthan are in the Barmer (figs. 2 and 4) and Merta Road districts (fig. 2). At Barmer there are three 5-15 meter zones of lignite at depths of 55 - 120 meters. At Merta Road there are several coal fields with a 7 - 8 meter lignite bed at depths of 65 - 150 meters.

The coal fields of Rajasthan are all near the Precambrian Indian shield inliers. Based on information available for this report, it appears that the shield area exposed in the Barmer-Bikaner area was also a positive feature during the early

Tertiary. The coal bearing Eocene(?) rocks at Bikaner were apparently deposited directly on basement. In the Barmer area, a Mesozoic section is preserved. (Poddar and Dhanasekaran,1986). The sedimentary section should thicken and coal potential should exist in all directions from the "Jaisalmer Jurassics" to the Thar of Pakistan, except possibly in the area directly between the shield outcrops of Barmer and Nagar Parkar, where the sedimentary section may be thin. Curiously, the Tertiary outcrops on the west side of the "Jaisalmer Jurassics" does not appear to have been explored for coal, despite reports of coal in the Sanu Formation from oil and gas test holes.

RESULTS OF WATER-WELL INVESTIGATIONS, SOUTHWESTERN THAR

Introduction

The British Overseas Development Agency (ODA), working with the Sindh Arid Zone Development Authority (SAZDA), drilled five test holes (subsequently converted to tubewells) in search of water in the southern part of the Thar desert during 1988 (fig 4). ODA retained Groundwater Development Consultants International Ltd. (GDC), a subsidiary of the Mott MacDonald Group, Karachi, as principal investigators for the program. In one of those holes, Khario Ghulam Shah - ODA2, dark "carbonaceous shale" (shale containing a significant amount of, but less than 50 percent organic matter) was encountered at about 129 meters depth. The interval from 129.6 m to 132.0 m was cored to test this rock (this is the only interval cored for the ODA program; all other drilled intervals were described from cuttings). GDC tentatively identified the cored material as carbonaceous shale containing some resinous lignite, and in the interest of finding out more

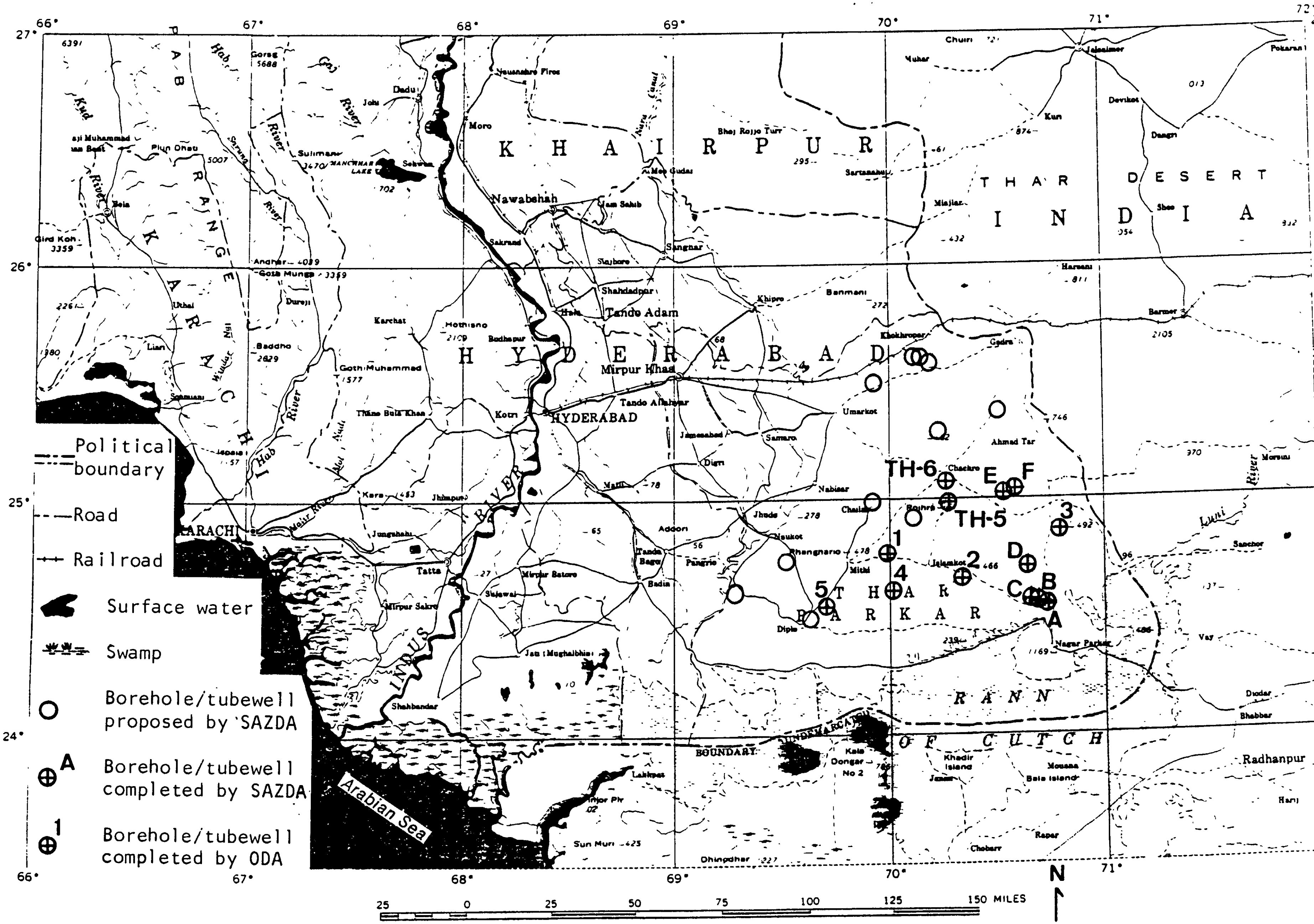


Figure 4. Location map of water-well drilling by the Sind Arid Zone Development Authority (SAZDA), and the British Overseas Development Authority (ODA), Thar Desert area of Pakistan.

about this material, contacted a number of agencies and commercial operators working in the area, including the GSP and USGS. A number of workers consider the material to be modern Indus basin peat (A.H. Kazmi, personal communication; note: GDC has requested that the results from other investigators of this material be considered proprietary and excluded from this report.) The distinction between peat and lignitic coal is more important in this case from a standpoint of occurrence than utilization. Both substances can readily be burned as fuel, but unlike the extensive coal deposits outlined earlier in this report, there are, to the author's knowledge, no peat deposits reported in the study area . While there could conceivably be scattered occurrences of peat in the Indus basin, based on the current climate and sediment input, the existence of commercial quantities of peat would seem unlikely. A USGS/GSP team visited GDC offices in Hyderabad on 18 Feb 89, and examined the core and cuttings of ODA2. Much of the material cored appears to the authors to be brown coal, and the cuttings from the enclosing rock appeared similar to coal bearing lower Tertiary rocks found elsewhere in Sindh. A few small samples of core were taken for testing in the U.S., and efforts began to collect data from other SAZDA water-well drilling in Thar where carbonaceous material was reported.

In addition to the 5 tubewells ODA had drilled in Thar by February 89, SAZDA had drilled 3 holes and sunk 3 tubewells, proposed 8 more holes and 4 more tubewells, and had one test hole (TH-5, fig. 4) in progress in the Dhaklo area (fig. 4). USGS was able to examine carbonaceous cuttings from one hole completed by

SAZDA, obtain information on other completed holes, and make arrangements for travelling to Dhaklo to geophysically log TH-5 and examine cuttings. The authors visited the Dhaklo site from March 18-19, 1989, to describe and sample cuttings and geophysically log the hole using USAID owned equipment. An additional tubewell pilot hole drilled by SAZDA near Chachro, TH-6, was visited by some of the GSP contributors to this paper in early July 1989 for the same purposes.

ODA drill holes

Rock descriptions

USGS and GSP described the ODA2 core and took several samples, and briefly examined, but did not describe, selected intervals of the ODA2 cuttings. Descriptions of the cuttings for all the ODA holes were provided by GDC and are included in Appendix 1. The description of the cored interval in ODA2 is shown in Appendix 2. Of the 2.4 meters cored, there was only about 1.5 meters of rock remaining in the box at the time of USGS/GSP inspection (presumably due to core loss and sampling by others).

While most of the cored material appeared to be brown coal to the authors, the distinction between peat and coal is somewhat arbitrary. Coal is defined as a readily combustible rock having more than 50 percent carbonaceous material by weight, which was formed by the chemical alteration and induration of plant remains (Wood and others, 1983). Peat is a water-saturated accumulation of partially decomposed plant remains and is a precursor to coal. The process of turning plants to peat is biologic, mostly bacterial. The process of turning peat to coal is geologic, through heat, pressure, and time. The degree of coalification is classified by rank. Higher rank coals are generally geologically older than lower rank coals, or, they have been subjected to locally strong geothermal forces. Some comparative measures of rank using European and American classification systems are shown in figure 5. Stach (1982, p.38) makes the following "not satisfactory" distinction between peat and brown coal (lignite):

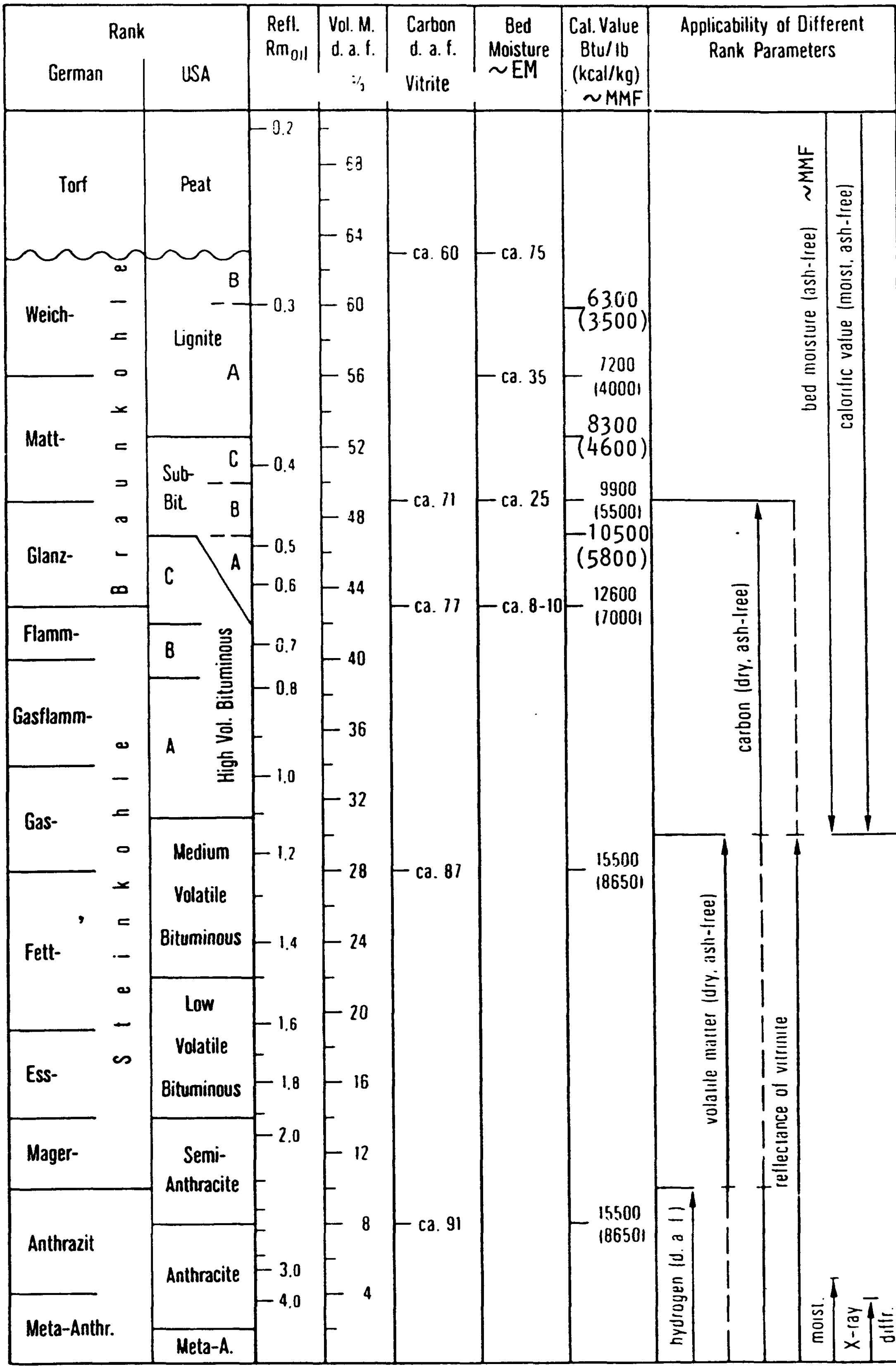
	Peat	Brown coal
% moisture	>75	<75
% carbon(daf*)	mostly < 60	mostly > 60
free cellulose	present	not present
can be cut	yes	no

* dry, ash-free

Normally, a reasonable distinction between peat and coal can be made based on the presence of vegetal structures and obvious moisture in fresh peat. The material examined was completely dried out, however, and probably contaminated with drilling mud in places. In general, it appears more similar to the soft brown coals of Australia than to peat in hand specimen. The very light weight also suggests it has an ash content well below carbonaceous shale (e.g. <50% dry). The low weight might be due to loss of pore moisture, however. On the other hand, there appears to be too much undegraded plant material in hand-specimen to completely rule out peat, and some of the material looks more earthy than typical brown coal.

In addition to the "lignitic" interval that was cored from 129.6 - 132.0 meters, GDC described carbonaceous cuttings from

Figure 5. The different stages of coalification according to the German (DIN) and North American (ASTM) classifications and their distinction on the basis of different physical and chemical rank parameters. The last column shows the applicability of various rank parameters to the different coalification stages. (modified from Stach, 1982)



126.5 - 129.6 m and 145.0 -183.8 m in ODA2. None of the other ODA holes recorded carbonaceous material, but a number of other possibly useful, but highly speculative, observations can be made. Absence of mica is a good indicator of bedrock in the Indus plain. In ODA3, the hole closest to the Indian border, the last mica occurred at 113.7 m. This suggests that the base of the conglomerate at 126.6 m might be the base of the Quaternary deposits. The relatively long interval of uniform claystone from 126.6 - 170.0 m, plus the apparent change in character of the limestone observed below 126.6 m supports this conclusion. The absence of mica and change in lithologic character below 88.9 m in ODA2 suggests this is possibly is an alluvial base. Also of interest as possible indicators of bedrock are the (contaminated?) shell fragments (5.8 - 20.7 m) and basalt fragments (?) (22.7 - 31.2 m) in ODA4.

Laboratory Results

A standard suite of coal analyses, including proximate and ultimate analysis, heating value, forms of sulfur, ash fusion temperature and surface moisture, were run on one ODA2 core sample. Because of the ambiguous appearance of the material, and the unreliability of the measured moisture values due to extreme desiccation, a number of other analytical tests were run on selected samples to determine the degree of coalification. In addition, spore pollen was examined in order to date the material.

Standard coal analyses.--The results of the standard coal analysis are shown in Appendix 3. Because of the small sample sizes available, two samples shown in Appendix 2, KGS-1 and KGS-2, were combined for the analysis (total weight 78g; actual intervals sampled were 130.90 - 130.94 m and 131.00 - 131.03 m).

Several of the parameters measured can be used to assess rank, but the rank determinations are questionable due to excessive drying of the sample. Normalizing the total carbon (dry) from 58.52 percent to an ash-free basis yields a d.a.f. total carbon of 71 percent, which is actually within the subbituminous range of figure 5. The d.a.f. volatile matter of 62.12 percent is close to the peat/lignite boundary of figure 5, however. Attempting to determine rank by calorific value as shown in figure 5 is probably unreliable in this case because of dubious moisture values due to prolonged storage in a dry climate. The air-drying loss from typical COALREAP core samples in Sindh was 20 to 30 percent, whereas the air-drying loss for KGS-1/2 was only 2 percent, indicating that pore moisture had been lost by the time the sample was analysed. The very low equilibrium moisture (normally approximately equivalent to bed moisture of fig. 5) is probably the result of pore collapse due to dessication. (If the pore space was not collapsed, the equilibrium moisture would be expected to be greater than the as-received moisture for samples which show no surficial moisture.) Converting the proximate analysis at equilibrium (E.M. basis) from Appendix 3 to moist, mineral-matter free (MMF) values by use of the Parr formula (approximately equal to the moist, ash-free values of fig. 5) yields 12,575 Btu/lb, which is in the high volatile bituminous range of figure 5. The same calculation using the as-received values yields 11,761 Btu/lb MMF, which is in the subbituminous range. Neither can be considered reliable determiners of rank in this case, but the Btu values do indicate that the material is readily combustable, and warrants exploration as a fuel resource whatever the true rank.

The d.a.f. volatile matter and heating values in Appendix 3, and the computed d.a.f. percent carbon for KGS-1/2, all fall within the ranges reported by Brown and Dey (1975) and Bhowmick and Roychandhuri (1982) for Rajasthan and Kutch coals. KGS-1/2 is at the high end of the reported volatile matter and heating values, however.

Coal petrology.-- An oriented microblock of Sample RMR-2 (Appendix 2) was examined petrographically to identify macerals (the discrete microscopic organic components that constitute coal), and the sample was pelletized for measuring reflectance by oil immersion microscopy. Results and conclusions of this examination are shown in Appendix 4.

The sample consisted primarily of the huminite maceral group (more or less the "woody" material in low rank coals), with abundant spores also present. Most of the huminite material was detritus or humic gel. A few strands of ulminite (gelified plant tissue with recognizable cell structures) were found in the top few mm, but no ungelified material with cell structure (texinite) was observed. Gelification of humic materials generally occurs at about the transition between the "soft" and "dull" brown coal stages of European coal classification (Stach, 1982, p.3 - approximately equivalent to the lignite A-B transition of U.S. terminology). The degree of gelification of huminite, plus the fact that the liptinite fluoresced under blue light, indicates that the material can be classified as a brown coal (Ron Stanton, USGS, written communication, Appendix 4).

Reflectance measurements can also be used to determine rank, as shown in figure 5. An average maximum huminite (vitrinite) reflectance in oil of 0.227 was also obtained for RMR-2. The maximum reflectance can be converted to the mean-random reflectance (Rm of fig. 5) by dividing by 1.06; thus Rm = 0.214. This reflectance is in the low to mid-peat range of figure 5. Stanton (Appendix 4) considered these results anomalous, and attributed the low reflectance to the granular maceral texture and probable oxidation of the core after drilling. Jin and Qin (1989) recorded mean random reflectances of 0.10 to 0.19 in 13 peat samples from China, and 0.28 to 0.33 in 4 brown coal samples.

Low-temperature ashing.-- Low-temperature ashing is a process by which the organic matter of a sample can be removed by oxidation, with minimal changes to the mineral assemblage of the inorganic residue, which can then be identified by other analytical techniques. Representative samples of RMR-1 and RMR-2 were ashed, and the ash was analysed by x-ray diffraction. A few unusual appearing large pyrite blebs from RMR-3 where also x-rayed. The objective of this series of tests was to see if any of the minerals which are frequently present in peat, but less common in coal, could be indentified. For instance, the three-layer clay mineral montmorillonite is usually altered to illite during coalification. The results of low-temperature ashing/x-ray diffraction are shown in appendix 5. Both samples were dominated by kaolinite, but the overall x-ray intensities for all constituents were low, possibly indicating much of the inorganic fraction of the sample is non-crystalline. None of the minerals that were identified are useful indicators of the degree of coalification. The bassinite, which is partially dehydrated gypsum, may be formed during the ashing process. While the peak intensities were low, they were discrete, without the many secondary peaks which are typical of the assemblages of hydrated minerals found in peat (Frank Dulong, USGS, personal communication). It is possible that the relatively high percentage of 11 to 21 percent low temperature ash present (%LTA appendix 5) represents sufficient detrital kaolinite to overprint the x-ray pattern of other minerals present. In general, the results of the LTA were inconclusive regarding the degree of coalification of these samples.

Nuclear magnetic resonance (NMR).-- NMR measures the absorption of electromagnetic radiation at selective frequencies by nuclei as they precess in the presence of a strong magnetic field. Hatcher and others (1988) have used ^{13}C-NMR spectra to investigate the coalification process by comparing the organic composition of coal, peat, and plant tissue. With cross-polarization magic angle spinning techniques (CPMAS), ^{13}C-NMR spectroscopy has the ability to directly determine the structure of hydrocarbon molecules in whole coal samples (Verheyen and others, 1984). ^{13}CPMAS NMR spectrum was obtained for sample RMR-2 and is shown in figure 6. Also shown in figure 6 are spectra for modern peat from the Dismal Swamp, USA, and Miocene brown coal from Victoria, Australia (Hatcher and others, 1988, poster).

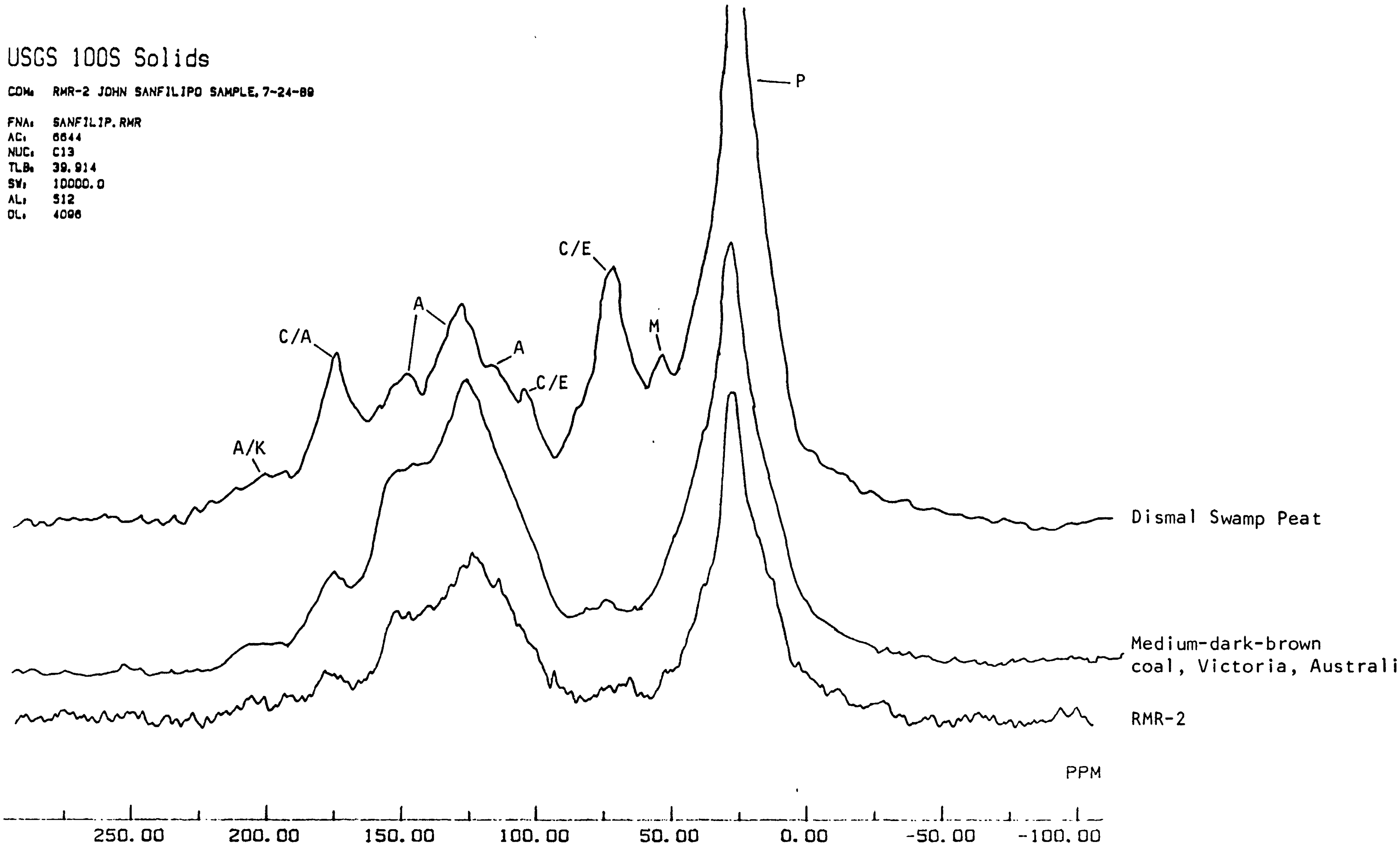


Figure 6. Comparison of ^{13}CPMAS-NMR spectra from modern peat, Miocene brown coal, and Thar Desert sample RMR-2. A/K = aldehyde/ketone, C/A = carboxyl/amide, A = aromatics, C/E = carbohydrate/ether, M = methoxyl (CH_3O functional group), P = paraffinics. Dismal swamp and Victoria spectra are from Hatcher and others, 1988, poster.

The RMR-2 spectra is nearly identical to the Victorian brown coal, which shows strong paraffinic and lignin-derived aromatic peaks (P and A respectively, fig. 6). The primary difference in the peat and brown coal spectra are the prominent carbohydrate/ether peaks at 72 and 106 ppm (C/E, fig. 6), which are present in the peat, but nearly absent from RMR-2 and the Victorian sample. The absence of these peaks represents the loss of cellulose during the coalification process (Hatcher and others, 1987). Diminution of the peak at 55 ppm represents loss of the methoxyl functional group in lignin during coalification (Hatcher, 1988b). The carboxyl/amide peaks (C/A fig. 6) are also greatly diminished in the brown coal and RMR-2 spectra. The loss of cellulose and methoxyl/carboxyl groups is compelling evidence that coalification has taken place in sample RMR-2 (Hatcher, personal communication).

Palynology.-- Spore pollen was examined from 4 ODA core samples, RMR-1, 2, 3 and 4. The results from the ODA holes are presented in Appendix 6, p.1-3. Most of the pollen in the core samples were small, undateable forms, but 7 species with known ranges were found. Frederikson (Appendix 6) concluded that the sample was late Paleocene to early Eocene in age.

SAZDA drill holes

Rock descriptions

Cuttings descriptions of the two SAZDA holes logged by USGS and GSP (TH-5 and TH-6, fig. 4) are included in appendix 7. The drill sites were not visited until the holes were nearly completed, so most cuttings were not actually observed by USGS/GSP until well after drilling. The SAZDA holes were sampled at regular intervals, but the SAZDA geologists only retain one sample between each major lithologic unit. The excess cuttings were discarded, so only a small portion of what was collected was actually observed by USGS/GSP, and the depths in Appendix 7 are very generalized. The cuttings logs are useful to distinguish basic lithologies and coaly intervals, but the actual positioning of lithologies by depth is best done in conjunction with the geophysical logs, as discussed in the next section.

Geophysical log interpretation

Open-hole natural gamma, neutron, single-point resistivity, and gamma-gamma (4-pi) density logs for TH-5 and TH-6 are provided in Appendix 8. The resistivity tool for TH-6 was not functioning properly. A semi-functional caliper log for TH-5 is also provided.

TH-5.-- A distinct shift in the gamma-neutron response can be seen below 123 m. Conglomeratic cuttings were recorded from 118 to 121 meters. The lithology above that interval is mostly fine-grained sandstone with some gritty beds; immediately below the rock becomes more lutaceous, with glauconite pellets and shell fragments present. The depth to bedrock is assumed to be 123 m. The gamma-neutron kick at 136.5 - 138.0 is possibly a limey unit.

Carbonaceous cuttings with plant debris were recorded from 146 to 151 and 163 to 189 m in TH-5. The geophysical logs indicate several zones of relatively thick coal beds may be present in these intervals, but interpretation of the logs is somewhat uncertain due to hole conditions. A gamma-gamma density log, which is ordinarily the primary tool to determine coal thickness, produced a very muted response when run at 2000 cps to total depth. The poor response was presumably due to the large hole diameter (nominally 8 in). The log was rerun at 1000 cps from 120 to 200 m, for more detail in the carbonaceous interval. Only the 1000 cps log is included herein. While more responsive in the coal-bearing intervals, the 1000 cps log is also very sensitive to hole rugosity, which has a signature similar to coal. When used in conjunction with the caliper log, however, hole caving can probably be distinguished from coaly intervals in TH-5. The response of the resistivity log for TH-5 is also somewhat muted, presumably due to very saline drilling fluids, but when used in conjunction with the other logs, it appears possible to pick coal from this log as well. The gamma-neutron log is normally used as a back-up log for picking coal, but because it is less affected by hole conditions, it is perhaps the most useful log for identifying coal in TH-5.

Coal picks, core loss, and other key lithologies are marked on the geophysical logs in Appendix 8. Based on the gamma-neutron-resistivity log, the following intervals are probably nearly all coal:

Depth	Thickness
145-147 m	2 m
161-162 m	1 m
164.5 - 174.5 m	10 m
177.5 - 181.5 m	4 m
192 - 194 m	2 m

It must be reemphasized that the condition of the hole, particularly rugosity, can cause responses which mimic coal in all the logs that were run, particularly for large-diameter holes like TH-5. It is possible that only a few thin coal beds are actually present, particularly in the 161 - 162 m interval, and that the carbonaceous cuttings and the geophysical log response below this interval are due solely to caving. In order to confirm coal, it will be necessary to core the inferred coal-bearing interval. If the interval from 164.5 to 181.5 is in fact a single coal bed with a 3 meter carbonaceous parting, it would be by far the thickest coal bed recorded in Pakistan to date.

Medium- to coarse-grained, relatively clean sandstone was recorded in cuttings from 211 to 287 meters. The actual position of this unit, which is the aquifer being developed by SAZDA, is about 206-283 m on the gamma-neutron log. The possible drilling mud contamination noted between about 251-253 m and 284-287 m actually appears to be lutaceous intervals from 249-253 and 283-292 m on the gamma-neutron log. Below 292 m, the unit appears to coarsen downwards on the gamma-neutron log, which was noted in cuttings, and it is not clear if the coarse-grained aquifer was completely penetrated or not.

TH-6.-- Correlation of cuttings to geophysical logs for TH-6 is similar to TH-5, except the 2000 cps density log response was better in TH-6, and 1000 cps was therefore not run.

A distinct break which may mark the depth to bedrock is noted on the gamma-neutron log at 40 m. Above this depth mostly fine-grained sand with lithic fragments was recovered in cuttings, whereas considerably finer material with few lithic fragments was recovered below 40 m. The limestone "lithic fragments" which were recovered between 66 and 69 m could be interpreted as bedded limestone based on the gamma-neutron log.

These could also correlate with similar lithic fragments recorded between 66 and 72 m in TH-5, in which case depth to bedrock might be considerably deeper than 40 m in TH-6, or alternatively, bedrock in TH-5 might be considerably shallower than indicated in the previous section. More or less uniform claystone with no distinctive geophysical signature was otherwise recovered from 40-157 m, except for sandy intervals from 110-119 m and 148-155 m, which are apparent on the gamma-neutron log. From 155 to 214 m there is a series of fining-up sand/shale sequences. The first carbonaceous streaks in TH-6 were noted at about 214 m. Between 214 and 240 m the interval was generally lutaceous, and contained carbonaceous streaks and glauconite. Carbonaceous shale was first noted in cuttings from 240.40-240.80 m. This appears to be coal on the geophysical logs. Cuttings from several intervals below this were clearly coal.

Based on the cuttings and geophysical logs the following intervals of TH-6 (density log) are interpreted to be coal:

Depth (m)	Thickness (m)	Comments
233.2-233.5	0.3	coal?
234.5-234.8	0.3	coal?
237.8-238.1	0.3	coal?
240.3-241.0	0.7	
244.6-252.2	7.6	shale 249.3-249.7
257.4-257.7	0.3	
258.0-258.4	0.4	
261.0-261.6	0.6	
269.4-271.8	2.4	
274.2-274.6	0.4	
296.8-299.6	2.8	bottom?

The interburden from 274.6-296.8 m was described as shale, but appears to be a fining-up sand/shale sequence on the gamma-neutron log.

One bag of cuttings from the 244.6-249.3 m interval was sent to Reston for examination. The material is similar in appearance to the darker parts of RMR-2 (appendix 2), but is somewhat darker, less earthy and more coaly in appearance. It is generally dark-brown and dull, with a few streaks of previtrain, and abundant resin. The chips are quite large and very tough, with a flaky to blocky texture and conchoidal fracture. Although some older peats can be similar in appearance, all of the sampled material appears to be coal. It has not been submitted for any laboratory testing as yet.

Correlation between TH-5 and TH-6.-- TH-5 and TH-6 are approximately 12 km apart. One possible correlation between the holes is shown in figure 7. The correlations between coal zones shown in the figure seem reasonably certain based on the gamma-neutron logs. The apparent thickening of individual coal beds from TH-6 to TH-5 might be real, or it might be due to better resolution of coal bed boundaries on the TH-6 density log. The intervals must be cored to resolve this question.

If the proposed correlation is correct, TH-6 probably completely, or nearly completely, penetrated the coal-bearing section. The approximate apparent dip between TH-5 and TH-6 would be less than half of one degree to the north.

The thickness of alluvial cover should be a major consideration in any coal exploration plans for Thar. Considerable coal would be lost in underground mining of beds as thick as those indicated in TH-5 and TH-6, and the thick aeolian cover would cause considerable shaft sinking problems. Finding coal that subcrops under shallow surficial deposits and can be strip mined should be

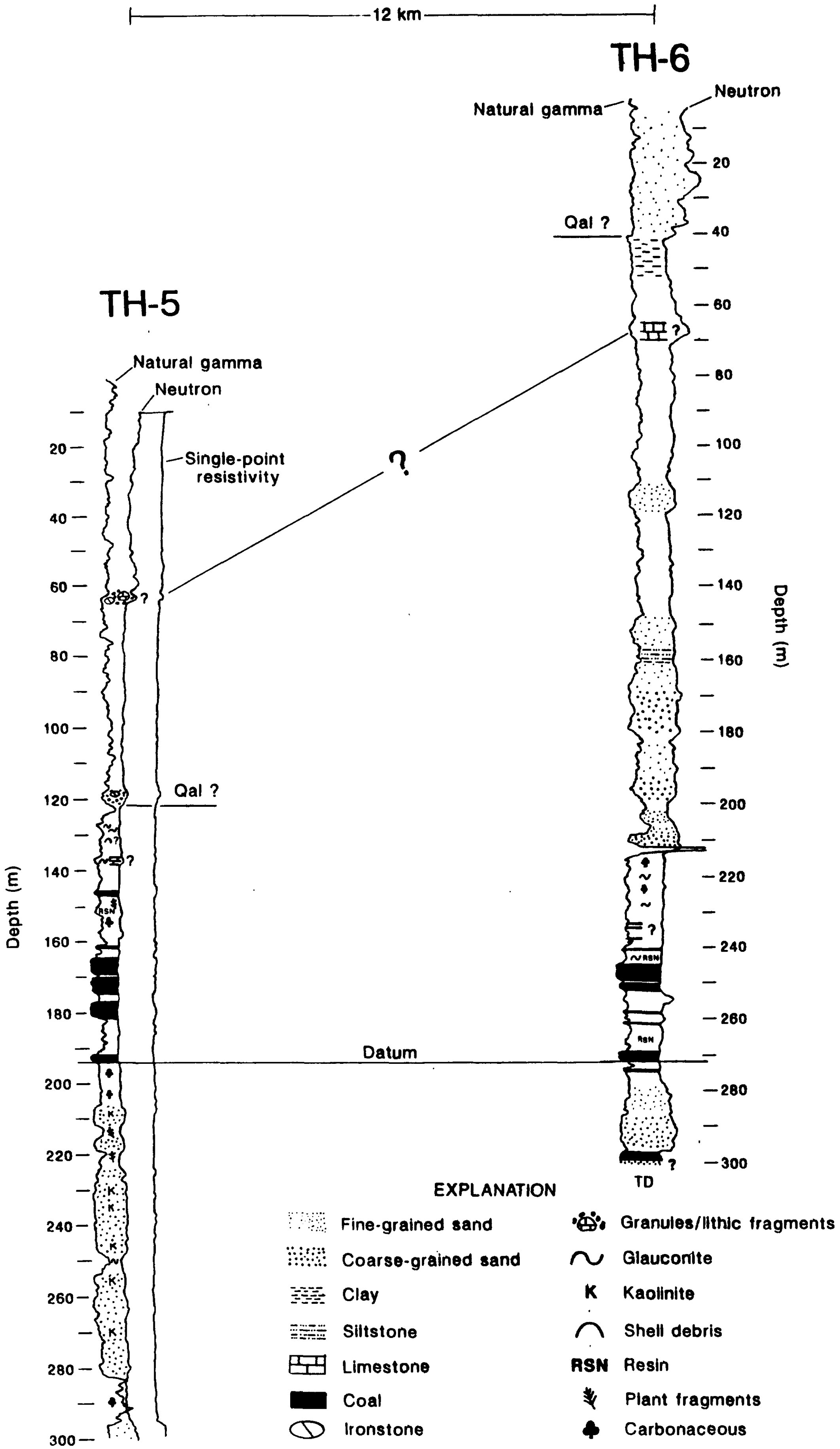


Figure 7. Possible correlations between drill holes TH-5 and TH-6. Lithologies are shown only for key beds. (Qal = Quaternary alluvium).

the major goal of any coal exploration program in Thar.

Correlating the depth to bedrock between TH-5 and TH-6 is impossible with existing information, however. It is unlikely, that the alluvial thickness would vary much over such a small area with no visible topography or bedrock outcrops. One of the depths to bedrock shown on fig. 7 (TH-5: 123 m, TH-6: 40 m), which are based solely on physical criteria, is probably erroneous. In order to accurately determine depth to bedrock, careful attention should be paid to drilling speeds for coal exploration holes drilled in Thar, and the first few holes drilled should be cored from relatively shallow depths.

Palynology

Results of spore pollen examinations for selected samples from TH-5 are shown in Appendix 6. Fourteen species with known ranges, and 6 new species that were first identified in earlier COALREAP studies in Sindh, were found (see Frederikson, 1989). The increase in species identified compared to the ODA core is probably due to the wider range of depth and lithologies sampled. Frederiksen (Appendix 6) concluded that the samples were most likely of early Eocene or possibly late Paleocene age.

Other Information

SAZDA reports a very coaly interval from about 220 - 245 m depth in test hole drilled near Mubarak Rind ("E" - Fig. 4). The hole was 305 m deep. A hole drilled by UNICEF and the Sindh Public Health Engineering Subdivision near Khokhropar (fig. 4) bottomed in coal from 204 - 211 m. Bedrock was reported at 123 m, but several limy intervals as shallow as 38 m were also reported.

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

Based on physical testing of a single core from one water well (ODA2), it appears that lignitic to subbituminous coal is present in the subsurface of the Thar desert of Pakistan. Based on geophysical and geologic evidence from two additional water wells (TH-5 and TH-6), located approximately 25 to 35 km north of ODA2, the coal appears to be significantly thicker than any yet recorded in Pakistan. Projection of known geology from other areas of Pakistan and India supports these ideas. The coal appears to be of early Paleogene age; more precise dating will require additional work and sample material. At present it is impossible to precisely correlate this material with the known coal-bearing rocks of Sindh Province Pakistan or western India. The material has a peaty appearance similar to that described for the lignites of western India. Its geographic position in the middle of the Indus basin and its stratigraphic position just below modern Indus alluvium in ODA2 have led some workers to conclude that this material is modern Indus basin peat, but its occurrence at depths up to 300 m in TH-6, more or less rules out this possibility. In any case, the material burns readily, and warrants further investigation for potential as a commercial fuel resource.

Recommendations

Due to the depth of aeolian and alluvial cover, and the lack of published subsurface information, a coal exploration program in the study area would ideally start with comprehensive inventory of existing water-well and oil and gas data (including western India). A number of agencies have explored for water in Thar and the Indus plain, and active oil and gas drilling and geophysical surveying have been conducted there for some time. The data inventory would ideally be followed up by ground geophysical surveys, such as resistivity, magnetics, or shallow seismic surveys, which might be especially useful if the highly reflective and probably magnetically susceptible Deccan traps extend in the subsurface to the surveyed areas. The objectives of such investigations would be to determine bedrock topography in order to effectively plan for drilling the areas where coal-bearing rocks should be the shallowest. If possible, surface investigations of the coal fields of Rajasthan and Kutch would also be useful.

Unfortunately, acquiring data from other agencies is difficult in Pakistan, and the lead time for geophysical prospecting would probably be beyond current COALREAP commitments. Under these circumstances, a modest drilling program to begin immediately is recommended. Some prospective drilling locations are shown in fig. 8. The order of priority should not be considered rigid. New information, particularly from additional water-well drilling, might considerably reorder or relocate the recommended drill locations.

Priority 1 is to twin TH-5 with a core hole, in order to confirm coal. The remainder of the drilling program would be contingent on the success of this hole. Priority 2 would be to establish the continuity of the coal below the much more accessible Indus Plain. Priority 3 would be to drill the

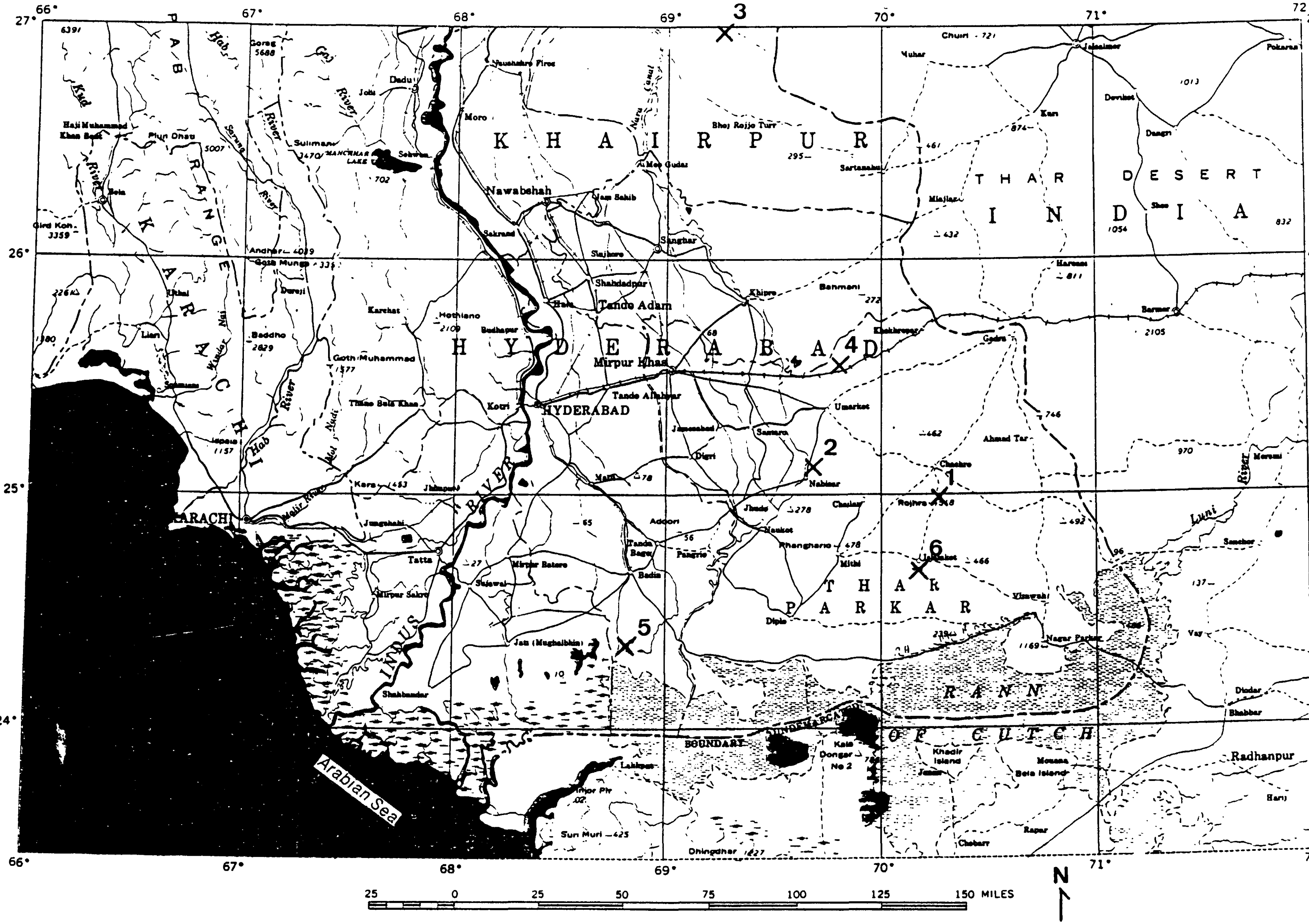


Figure 8. Recommended drilling locations, Thar desert area, Pakistan, numbered in order of priority from 1 to 6.

Jacobabad High. The exact location would be determined after field investigations of the Eocene outcrop at the Khairpur outlier, and at least a cursory investigation of existing oil and gas data in the surrounding areas. While this location might be expected to be the shallowest to coal, Singh (1976) reports the depth to the Ranikot Formation in an oil well drilled at Kharatar (some 125 km NE of 3, fig. 8, approx. 27.5 degrees N, 70 degrees E) is over 700 m. Kharatar is probably north of the axis of the Jacobabad High, but a careful examination of all available data should be made before locating the priority 3 hole. Priority 4 would be a hole near the Hyderabad-Barmer railway, west of the Khokhropar UNICEF hole. Priority 5 would be a hole just north of the coalfields of Lakhpat India. An investigation of oil and gas wells of the Badin area would be required before exactly locating the hole, which might be anywhere between Nagar Parkar and Jati (Mughalbhin). Priority 6 would be a hole just south of Islamkot, to correlate the coal encountered in ODA2 with other holes and to determine the regional dip away from the shield outcrops at Nagar Parkar.

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APPENDICES 1 -7

Appendix 1

Lithologic descriptions of ODA drill hole cuttings.

LITHOLOGY

SETTLEMENT Mithrio Bhatti **REFERENCE** M001 **TUBEWELL Nr** ODA1

Depth (m)	Description of Cutting Returns	
0 - 66.0	SAND	fine/medium or fine, well sorted, light grey/brown, 15% black mica, various trace minerals, variably calcareous, variably indurated with a few polygrains in places; fine, very calcareous, light grey coloured silty? sand as two layers at approx. 28.5-29.6 m and 31.0-32.7 m
66.0 - 71.0	SAND	fine/medium, less well sorted than above with coarse and very coarse quartz grains, orange/brown, 15% black mica, calcareous, minor clay
71.0 - 87.5	clayey SAND	very fine/fine, mottled white, yellow and brown, 10% black mica, weakly calcareous, some clay of various colours; clean, very fine, colourless sand with 10% black mica at approx. 78-78.8 m
87.5 - 95.5	SAND	fine or fine/medium, moderately sorted, colourless, 5% black mica, laterite near base, less trace minerals than 0-66.0 m, non-calcareous, polygrains in places
95.5 - 113.0	CLAY	yellow, brown, red and grey, gritty with fine sand which contains 5% black mica, laterite at various horizons
113.0- 115.0	CLAY	red, some mottling, some laterite
115.0- 116.1	LATERITE	reddy brown, hard, angular, with some brown/red clay

Appendix 1

LITHOLOGY

SETTLEMENT Kario Ghulam Shah **REFERENCE** M013 **TUBEWELL Nr** ODA2

Depth (m)	**Description of Cutting Returns**
0 - 47.1	SAND fine or fine/medium, mostly well sorted, yellow or grey/brown, 10-15% black mica, variably indurated with some polygrains, weakly or moderately calcareous; fine, moderately sorted, grey, very calcareous, silty sand at approx. 31.3-32.5 m; very calcareous, fine sand at approx. 40.5-42.4 m; medium, moderately sorted, orange/yellow sand with 10% black mica at approx. 42.4-43.4 m
47.1 - 53.0	SAND fine/medium or medium and coarse, moderately or poorly sorted, mostly orange/brown, 10-15% black mica, very calcareous towards top, low % laterite below 52.3 m
53.0 - 70.1	SAND + CLAY very fine or fine, poorly sorted colourless SAND, 5% black mica, weakly calcareous, some grey/white silt, some laterite cuttings, some mottling; brown CLAY present as layers (see core) but elsewhere may be as clasts within a sandy matrix (sample M014W2S3 from Saleh jo tar is very similar when crushed)
70.1 - 73.0	sandy CLAY brick red coloured, rare black mica, some laterite cuttings, some coarse yellow quartz
73.0 - 78.2	CLAY + SAND coarse, poorly sorted SAND; cream/brown or red/brown CLAY, some laterite cuttings, weakly calcareous; could be a conglomerate
78.2 - 81.8	SAND very fine, poorly sorted, brown, rare black mica, some laterite, some silty material, moderately calcareous
81.8 - 88.9	clayey SAND very fine, poorly sorted including some coarse yellow quartz, calcareous, rare black mica, some laterite, multicoloured clay
88.9 - 94.9	SAND medium or very coarse, moderately or poorly sorted, orange/brown (well stained), some laterite, rare grey silt, no black mica, not calcareous, no polygrains
94.9 - 108.0	SILT grey, red and yellow, 10% hard angular laterite cuttings, a little fine/medium and coarser unstained sand with no black mica, rare clay

Appendix 1

LITHOLOGY AT KARIO GHULAM SHAH (M013) - Continued

108.0 - 110.5 SAND fine/medium, poorly sorted, unstained, no black mica, calcareous

110.5 - 122.7 SILT + LATERITE grey, red, white, red/brown and yellow, high % subangular laterite cuttings, weakly calcareous, some fine/medium sand plus rare white grains(?) increasing below 114.2 m

122.7 - 126.5 silty SAND fine/medium, quite well sorted, not calcareous below 123 m, no black mica, laterite layers, separate grey silt cuttings

126.5 - 129.6 SAND fine/medium, well sorted, unstained quartz, no black mica, some black 'carbonaceous shale' (this is soft and leaves a dark brown trace) ABDT KAOLINITE - JRS

129.6 - 132.0 CARBONACEOUS SHALE very fine, dark but variably coloured, some resin and amber, some lignite, rare chalcopyrite
CORED

132.0 - 139.4 sandy CLAY dark brown but also many other colours, with medium, poorly sorted sand, no black mica

139.4 - 145.0 CLAYSTONE grey/green and black in varying proportions, the claystone cuttings are hard 'pellets', rare fine, colourless sand, very rare white clay

145.0 - 150.5 CLAYSTONE black

150.5 - 164.0 CLAYSTONE light and dark grey, rare lignite and pyrite(?), rare silt, some carbonaceous shale, rare white clay, rare hard red fragments(?) less than 5 mm in size

164.0 - 169.0 CARBONACEOUS SHALE black, soft, with a vague smell of hydrogen sulphide

169.0 - 183.8 CLAYSTONE mostly grey, with some layers of carbonaceous shale, very rare yellow and white/grey and red silt, rare quartz

Appendix 1

LITHOLOGY

SETTLEMENT Ohramar **REFERENCE** N016 **TUBEWELL Nr** ODA3

Depth	Description
0 - 2.8	CLAY grey, gritty with a little very fine sand containing 10% black mica, some shell fragments
2.8 - 42.4	SAND fine/medium or fine, well or fairly well sorted, grey/brown, 15-20% black mica, mostly moderately calcareous, rare polygrains
42.4 - 51.2	SAND fine/medium or medium or coarse, less well sorted than above, more variably coloured (grey/brown or orange/brown), 10% black mica, 5% white opaque grains(?), moderately to weakly calcareous, rare polygrains
51.2 - 63.5	SAND fine, quite well sorted, light grey/brown, 5-10% black mica, weakly or moderately calcareous, rare polygrains; slightly silty at about 57 m
63.5 - 69.2	SAND variable: fine or fine/medium or coarse, poorly or quite well sorted, grey/brown or orangey brown, subround or round grains, less than 10% black mica; rare laterite cuttings at approx. 67 m; highly calcareous and silty from about 67 m down
69.2 - 73.8	CONGLOMERATE angular medium/coarse cuttings (the clasts) with fine/medium very poorly sorted often cemented quartz sand (the matrix); the clasts are many colours including pink, grey brown black and white, many of which are polygrains of limestone; the sand contains very little black mica, but there are some polygrains and the bed is very hard at 71.32 m and 73.62-73.82 m
73.8 - 79.2	CONGLOMERATE/VARIABLE BED as above, but more angular buff limestone/marl(?) cuttings and less pink, also more variable; quite clay-rich from about 76.6 m and this may be a separate bed
79.2 - 81.3	GRITTY CLAY grey/brown, gritty with a little fine/medium very poorly sorted sand, a little brown claystone, extremely calcareous
81.3 - 84.3	CLAYEY SAND fine/medium and fine, very poorly sorted, light tan brown, 5 % black mica, extremely calcareous; clayey at 83 m

Appendix 1

LITHOLOGY AT OHRAMAR (N016) - Continued

84.3 - 95.5	SAND	medium or medium/coarse, quite poorly sorted, orangey brown, 5% black mineral (mica?), 5-10% white opaque grains(?) and separate pink trace mineral(?), weakly to very weakly calcareous
95.5 - 99.0	CONGLOMERATE	medium, poorly sorted, brown, 75% quartz sand, 20% angular buff limestone/ marl(?), a little clay, rare black and pink limestone polygrains, 5% black mineral(mica?)
99.0 - 103.5	SANDSTONE	medium, poorly sorted, grey/brown, rare black minerals, some polygrains, moderately calcareous
103.5- 113.7	SANDSTONE	variable: medium and fine/medium, quite poorly or very poorly sorted, tan brown, 5-10% black mineral (some of this is mica), some tan claystone, some pink limestone, some yellow and grey silt, rare polygrains, moderately calcareous, possibly some conglomerate
113.7- 126.6	CONGLOMERATE	variable: very poorly sorted fine/medium quartz sand (the matrix) and more angular cuttings of pink or white limestone, buff limestone/marl(?), tan brown clay (the clasts), highly calcareous; the sand and clay probably also exist as separate layers
126.6- 170.0	CLAY	tan brown also multicoloured, lighter coloured at depth, gritty with fine sand near top, some white soft coarse cuttings of limestone in places, some black grains(?), rare laterite at about 150 m
170.0- 183.85	CLAYEY SAND	medium, poorly sorted, brown, rare black grains(?), variable % multicoloured clay increasing with depth, rare laterite LOOKS LIKE GRANITE WASH - JRS

Appendix 1

LITHOLOGY

SETTLEMENT Chaunihar **REFERENCE** M024 **TUBEWELL Nr** ODA4

Depth (m)	Description of Cutting Returns	
0 - 2.7	SAND	fine, moderately sorted, orange/brown, 15% black mica, weakly calcareous
2.7 - 5.8	SAND	fine and fine/medium, moderately sorted, light grey/brown, 15% black mica, moderately calcareous, some coarse quartz grains, some polygrains, possibly silty
5.8 - 20.7	SAND	fine/medium or fine or very fine, quite poorly sorted, orange/brown or light orange/brown or grey/brown, 10-20% black mica, very rare concretions near top, variable % polygrains but high % near base, moderately calcareous, some shell fregments which may have blown in during sampling and bagging
20.7- 22.7	SAND	fine, poorly sorted, orange/brown and well stained, 10-15% black mica, some polygrains, moderately calcareous
22.7- 31.2	SAND	fine, poorly or moderately sorted, light orange/brown, 10-20% black mica, some medium/coarse quartz grains, some coarse basalt(?) and white weakly calcareous concretions near top, high % polygrains in places, moderately calcareous
31.2- 35.5	SAND	fine, poorly sorted, light grey/brown, 15% black mica, high % polygrains, moderately calcareous
35.5- 44.3	SAND	very fine/fine or fine, moderately sorted, light creamy orange/brown, 10% black mica, possibly silty in places, rare polygrains, highly calcareous
44.3- 49.9	SAND	fine, quite poorly sorted, orange/brown, 20% black mica, some polygrains, some medium/coarse soft white calcareous polygrains
49.9- 53.2	SAND	fine, moderately sorted, light grey brown, highly calcareous, possibly silty
53.2- 64.5	SAND	fine, moderately sorted, mostly light grey/brown, 15-20% black mica, moderately or highly calcareous, rare polygrains and white concretions, silty near base

Appendix 1

LITHOLOGY AT CHAUNIHAR (ODA4) - Continued

64.5- 73.9	CLAY	light of dark grey, sticky, gritty in places with black mica and fine colourless quartz
73.9- 80.0	SAND	fine, poorly sorted, colourless quartz, 5% black mica, moderately calcareous, some grey clay probably as layers
80.0- 95.0	lateritic SAND	predominantly fine, poorly sorted, colourless quartz, 5% black mica, more than 10% laterite cuttings which are coarser than the quartz, some yellowy brown concretions, weakly or very weakly calcareous, grey clay as layers, samples are coloured depending on proportion of clay and laterite
95.0- 98.7	SAND	very fine, poorly sorted, tanbrown, some grey clay, laterite

Appendix 1

LITHOLOGY

SETTLEMENT Karihar **REFERENCE** D005 **TUBEWELL Nr** ODA5

Depth (m)	Description of Cutting Returns
0 - 53.5	SAND fine/medium or lesser fine, mostly moderately sorted, grey brown, 15% black mica above 26 m 10% below, mostly moderately calcareous, rare polygrains; highly calcareous at approx. 37-41 m and 45-50 m; possibly silty at approx. 29.5-32.4 and 45-47 m
53.5- 56.0	CONGLOMERATE subangular medium and coarse/very coarse cream/brown limestone cuttings (the clasts) and fine/medium sand, 5% black mica, some polygrains (the matrix), rare grey clay
56.0- 57.0	SAND fine, poorly sorted, grey, 5% black mica(?), rare clay
57.0- 59.0	CLAY grey, gritty

Description of cored interval, tubewell ODA2

Drilled by: British Overseas Development Authority
Location: Approx 24 40'00"N, 70 19'15"E, near Khario Ghulam Shah village
Total depth: 183.8 m
Cored interval: 129.60 - 132.00 m
Depth to bedrock: 123(?) m
Sampled by: RMR - C. Wnuk (USGS), M. Fariduddin (GSP)
KGS - J. SanFilipo (USGS)
Described by: J. SanFilipo (USGS)

Sample no.*	Approx depth (m)	Lithology
RMR-2	129.60 - 130.00	Brown-coal, grades dark, abundant resin.
RMR-1	130.00 - 130.10	Dark-brown coal, no resin, possibly compressed plant debris.
RMR-3	130.10 - 130.90	Dark-gray claystone, silty, sandy, scattered carb debris and resin, green films, sulfur odor.
KGS-1	130.90 - 131.00	Dark-brown coal, sparse to moderate resin, similar to RMR-1/RMR-2.
KGS-2	131.00 - 131.20	Light-brown coal, abundant to sparse resin, similar to RMR-2/RMR-4.
RMR-4	131.20 - 132.00	Light brown coal, sparse resin.

*only a few cm of each interval were sampled by USGS/GSP

Appendix 3

COAL-ANALYSIS REPORT

TO: UNITED STATES GEOLOGICAL SURVEY
~~National Center~~
~~Mail Stop 956~~
~~Reston, Virginia 22092~~

DATE 8-17-89 LAB NO 890423 - 001

DRILL HOLE SEAM: PROJECT:

PROPERTY DEPTH: THICKNESS:

REMARKS: Sample Identification: KGS-1/2

PROXIMATE ANALYSIS	E.M. basis	As received	Dry basis	M&A free basis
% Moisture	3.30	8.34		
% Ash	17.23	16.33	17.81	
% Volatile	49.37	46.80	51.06	62.12
% Fixed Carbon	30.10	28.53	31.13	37.88
Btu	10169	9639	10516	12795
% Sulfur	3.43	3.25	3.55	4.32

lbs SUL/MM BTU = 3.37

SULFUR FORMS	E.M. basis	As received	Dry basis	M&A free basis
% Pyritic Sulfur	2.11	2.00	2.19	2.66
% Sulfate Sulfur	0.05	0.05	0.05	0.06
% Organic Sulfur	1.27	1.20	1.31	1.60
% Total Sulfur	3.43	3.25	3.55	4.32

WATER SOLUBLE ALKALIES

% Na_2O =

% K_2O =

FUSION TEMPERATURE OF ASH	Reducing	Oxidizing
Initial Deformation	1990 °F	°F
Softening (H = W)	2020 °F	°F
Hemispherical (H = ½ W)	2040 °F	°F
Fluid	2050 °F	°F

H is Cone Height
W is Cone Width

AIR DRYING LOSS = 2.28
HARDGROVE GRINDABILITY INDEX =
FREE SWELLING INDEX = 0.0
WATER SOLUBLE CHLORINE =
APPARENT SPECIFIC GRAVITY =

ULTIMATE ANALYSIS	E.M. basis	As received	Dry basis
Moisture			
Carbon	56.59	53.64	58.52
Hydrogen	5.56	5.85	5.37
Nitrogen	0.45	0.43	0.47
Chlorine	0.05	0.05	0.05
Sulfur	3.43	3.25	3.55
Ash	17.23	16.33	17.81
Oxygen (diff)	16.69	20.45	14.23

MINERAL ANALYSIS	% Wt. Ignited Basis
Phos pentoxide, P_2O_5	
Silica, SiO_2	
Ferric oxide, Fe_2O_3	
Alumina, Al_2O_3	
Titania, TiO_2	
Lime, CaO	
Magnesia, MgO	
Sulfur trioxide, SO_3	
Potassium oxide, K_2O	
Sodium oxide, Na_2O	
Undetermined	
BASE/ACID RATIO	

Terry Rollins
DICKINSON LABORATORIES, INC.

DICKINSON LABORATORIES, INC.
COAL & OIL SHALE ANALYSTS
P.O. BOX 12006 EL PASO, TEXAS 79913-0006 915/584-9496

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA 22092

August 2, 1989

To: John SanFilipo

From: Ron Stanton

Subject: Coal/peat ?? from Pakistan

Jim and I examined the sample of material that you brought back from Pakistan. My feeling is that this is brown coal in rank even though the reflectance is slightly lower than expected. There is no observable plant cell wall material (textinite) that would indicate a soft brown coal or peat. In addition, the material consists dominantly of plant attritus with very few huminite pieces from which a reflectance could be obtained. To further question the reliability of the reflectance data, I fear that this has been subjected to considerable oxidation because it is not possible to acquire a suitable polish for reflectance measurement.

As I stated to you earlier, another line of analysis that may be considered is Carbon 14 dating. If a date can be acquired then the hypothesis that this is a river peat may be valid, however, if no date can be asssigned, then there would be one more piece of data that suggests that this is from a brown coal deposit.

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA 22092

VITRINITE REFLECTANCE -- PELLET RMR 2

0.236	0.212	0.263	0.227	0.206
0.249	0.218	0.264	0.235	0.296
0.291	0.296	0.253	0.257	0.257
0.276	0.248	0.231	0.303	0.217
0.231	0.209	0.239	0.215	0.296
0.176	0.141	0.173	0.223	0.163
0.146	0.158	0.165	0.244	0.228
0.263	0.274	0.272	0.194	0.206
0.196	0.170	0.243	0.243	0.236
0.255	0.197	0.146	0.203	0.220

mean = 0.227 std. dev. = 0.042

United States Department of the Interior

GEOLOGICAL SURVEY
RESTON, VA 22092

MEMORANDUM

TO: **John R. SanFilipo**

FROM: **Frank T. Dulong**

DATE: **July 19, 1989**

SUBJECT: **Pakistan brown coal, selected samples**

XRDID	DESCRIPTION	%LTA
RMR 1	Pakistan "Brown Coal", water well	20.6
RMR 2	Pakistan "Brown Coal", water well	11.3
RMR 3	selected blebs, marcasite/pyrite	NA

RMR-1: Dominated by kaolinite, with a substantial amount of marcasite, minor quartz and bassinite. The over all intensity of the sample is low with alot of diffuse scattering, indicating either: 1) incomplete ashing; or 2) a substantial portion of amorphus material.

RMR-2 Subequal amounts of quartz and kaolinite with minor bassinite. As with RMR-1 the intensity for the sample is low.

RMR-3 All pyrite, no hint of marcasite.

SEMIQUANTITATIVE MINERALOGY, SUMMARY

XRDID	QTZ	KAOL	SID	PYR	MARC	SPHL	BASS
RMR-1	7	66	<1	2*	14	2*	8
RMR-2	48	41	3				7
RMR-3				100			

QTZ= quartz, KAOL= kaolinite, SID= siderite, PYR= pyrite, MARC= marcasite, SPHL= sphalerite, and BASS= bassinite. A stared (*) value indicates the lowest level of probability. Not all of the necessary peaks are present to establish a highly probable qualitative identification.

cc S.P. Schweinfurth
C.B. Cecil

U.S. DEPARTMENT OF THE INTERIOR
GEOLOGICAL SURVEY

REPORT ON REFERRED FOSSILS

Stratigraphic Range Paleocene-Eocene		Shipment Number C-89-1
General Locality (state, country, ocean, etc.) Pakistan		Number of Samples 10
Quadrangle or Area Thar Desert		Region (county, province, sea, etc.) Sind Province
Fossil Type(s) Sporomorphs		Referred By John SanFilipo
Formation		Report By Norm Frederiksen
Latitude deg. min. 24°40'00" N	Longitude deg. min. 70°19'15" E	Report Date Sept. 1, 1989

This report concerns 10 samples from two water wells:

Borehole: Overseas Development Authority tubewell ODA2
Location: Approx. 24°40'00" N, 70°19'15" E, near Kario Ghulam Shah village
Total depth: 183.8 m
Cored interval: 129.60 - 132.00
Depth to bedrock: 123(?) m

Palynology Sample		Field No.	Approx. depth (m)	Lithology
R 4328A	A	RMR-2	129.60-129.66	Brown coal/carb sh, abundant resin
	B	RMR-1	130.00-130.04	Dark brown coal/carb sh, no resin
	C	RMR-3	130.4-130.5	Dark gray claystone, silty, sandy, scattered carb debris and resin
	D	RMR-4	131.2-132.0	Light brown coal/carb sh, sparse resin

Borehole: Sind Arid Zone Development Authority Test Hole 5 (SAZDA TH-5)
Location: Approx. 24°59'15" N, 70°14'00" E, near Dhaklo village
Total depth: 300.86 m
Cored interval: none
Depth to bedrock: 122 m

Palynology Sample		Field No.	Approx. depth* (m)	Lithology
R 4329A	A	TH-5-24	134.30-141.50	Gray siltstone, resinous
	B	TH-5-25	141.50-145.86	Brown claystone, glauconite(?)
	C	TH-5-26	145.86-150.80	Carb sh, coaly, resinous, pyritic, plant debris
	D	TH-5-29	163.50-176.00	Carb shale, coaly
	E	TH-5-30	176.00-180.86	Carb sh/siltstone
	F	TH-5-35	191.50-209.30	Gray shale, carb debris

* as reported by SAZDA

R4328 samples (core samples)

Following are pollen species of known age, and their ranges. * indicates that this species does not appear in the literature; it is known only from my work on the upper Paleocene of the Lower Indus coal field.

Species	Olig.- Mioc.	Up. Eoc.	Mid. Eoc.	Low. Eoc.	Paleocene
Cupanieidites flacciditormis Venkatachala & Rawat 1972		?	?	X	X
Dermatobrevicolporites exaltus Kar 1985				X	
Intrareticulitis brevis (Sah & Kar 1970) Kar 1985				X	X
Lakiapollis ovatus Venkatachala & Kar 1969	X	X	X	X	X
Proxapertites assamicus (Sah & Dutta 1966) Singh 1975				X	X
Retistephanocolpites spp.		X	X	X	X
Symplocoipollenites constrictus Sah & Kar 1970				X	?

These were coaly samples that contained a lot of pollen but mostly small forms whose stratigraphic ranges are known poorly, if at all. From the small number of datable species, it appears that the samples could be either Paleocene or early Eocene in age. For whatever it's worth, these samples lack most of the late Paleocene species that I have found in the Lower Indus coal field.

R4329 samples (cuttings)

Species	Olig.-Mioc.	Up. Eoc.	Mid. Eoc.	Low. Eoc.	Paleocene
Assamialetes emendatus Singh 1975		X	X	X	X
Cupanieidites flaccidiformis Venkatachala & Rawat 1972		?	?	X	X
Dermatobrevicolporites dermatus (Sah & Kar 1970) Kar 1985			X	X	
Intrareticulitis brevis (Sah & Kar 1970) Kar 1985				X	X
Lakiapollis ovatus Venkatachala & Kar 1969	X	X	X	X	X
Longapertites retipilatus Kar 1985			X		X
Longapertites sp. A					*
Longapertites sp. F					*
Meliapollis quadrangulus Sah & Kar 1970				X	X
Meliapollis ramanujamii Sah & Kar 1970				X	X
Palaeocaesalpiniaceaepites eocenicus Biswas 1962		X	X	X	X
Pellicieroipollis langenheimii Sah & Kar 1970			X	X	
Polygalacidites gujaratensis Kar 1985				X	
Porocolpopollenites aff. *P. ollivierae* Gruas-Cavagnetto 1976					*
Proxapertites assamicus (Sah & Dutta 1966) Singh 1975		X	X	X	X

Species	Olig.- Mioc.	Up. Eoc.	Mid. Eoc.	Low. Eoc.	Paleocene
Retistephanocolpites spp.		X	X	X	X
Spinaepollis sp. A					*
Spinizonocolpites prominatus (McIntyre 1965) Stover & Evans 1973	X	X	X	X	X
Spinizonocolpites sp. A					*
New genus A sp. C					*

Six species in this list are known only from the upper Paleocene of Sind Province; the tops of their ranges are not well known. If we disregard these species, and look only at species not known to range higher than the Eocene, then 9 species on the list are known from the Paleocene, 12 certainly or presumably from the lower Eocene, 7 or 8 from the middle Eocene, and 4 or 5 from the upper Eocene. The list includes several species that don't range higher than the lower Eocene, and several that don't range lower than the lower Eocene. In short, the most likely age is early Eocene. However, since quite a few species are present that so far are known only from the Paleocene (of Sind Province), the samples are probably not younger than earliest Eocene. On the other hand, since these are cuttings, it is possible that the samples are Paleocene in age and that the Eocene material is contamination from up-hole.

Norm Frederiksen

Norm Frederiksen

HAD

Appendix 7
Lithologic logs of drill holes TH-5 and TH-6

Lithologic log: Drill hole TH-5

Drilled by Sind Arid Zone Development Authority (SAZDA)
Location: Approx. 24°59'15"N, 70°14'00"E, near Dhaklo village
Total depth: 300.86 m
Cored intervals: none
Lithology logged by: C. Wnuk and J.SanFilipo (USGS)
M. Fariduddin and S. A. Khan (GSP)
18 - 19 Mar 89

(note: each unit refers to an interval of samples that were bagged and labeled as a discrete lithologic unit by SAZDA geologists prior to USGS/GSP inspection)

Depth (m)	Description of cuttings
1) 0.00 - 7.36	Sandstone, very fine to medium-grained, dirty, contains abundant dark minerals, yellow-brown, similar to the surface.
2) 7.36 - 13.80	Sandstone, gray-brown, fine- to very fine grained, well-cemented, calcareous, abundant dark minerals.
3) 13.80 - 18.86	Sandstone, same as no. 2, with coarse- to gravel-size quartz, biotite, lithic fragments.
4) 18.86 - 22.80	Sandstone, same as no. 3.
5) 22.80 - 37.50	Sandstone, fine- to very fine grained, calcareous, abundant dark minerals, less cement than above.
6) 37.50 - 48.00	Sandstone, same as no. 5, but well-cemented.
7) 48.00 - 57.30	Sandstone, same as no. 5.
8) 57.30 - 66.50	Sandstone, same as no. 5.
9) 66.50 - 71.80	Sandstone, same as no. 5, with coarse to granular subrounded quartz grains and limestone fragments up to 1 cm size.
10) 71.80 - 72.86	Sandstone, pinkish brown, poorly sorted, very fine to granular quartz, maroon ironstone pebbles and fragments, rounded coarse limestone lithic grains, lithic fragments of white fine-grained sandstone.
11) 72.86 - 75.50	Sandstone same as no. 10.
12) 75.50 - 82.80	Mostly white fine-grained lithic sandstone fragments and reddish brown clay, with sparse disseminated fine-grained quartz.
13) 82.80 - 88.00	Sandstone, very fine grained, mottled white and yellowish brown, with ironstone granule and other fine-grained dark minerals.

14)	88.00 - 96.80	Sandstone, mottled dirty-white and reddish-brown, very fine grained, with very fine grained dark minerals, sparse ironstone granules, very slightly calcareous.
15)	96.80 - 98.30	Ironstone pebble and granule conglomerate, reddish-brown, few quartz granules, some sandstone like no. 14.
16)	98.30 - 106.86	Sandstone, fine- to very fine grained, red with yellow and brown mottling, contains scattered ironstone pebbles and granules.
17)	106.86 - 112.75	Sandstone, yellow-brown with red and white mottling, very fine grained with scattered very coarse quartz grains.
18)	112.75 - 118.00	Sandstone, very fine grained, few medium grains, very dirty, ironstone pebbles.
19)	118.00 - 121.30	Conglomerate, medium-grained to granular quartz, 50 pct. ironstone granules.
20)	121.30 - 123.00	Sandstone, white, very fine to granular, poorly sorted, dirty, rare ironstone granules.
21)	123.00 - 125.30	Claystone, dark gray, and sandstone, same as no. 20.
22)	125.30 - 130.50	Siltstone/claystone, dark gray, laminated, contains abundant glauconite.
23)	130.50 - 134.50	Claystone, black, contains resin blebs, possible shell fragments, no glauconite.
24)	134.50 - 141.50	Siltstone, dark gray, sparse glauconite pellets.
25)	141.50 - 145.86	Claystone, dark grey to black, glauconite at places.
26)	145.86 - 150.80	Carbonaceous shale, dark brown, argillaceous, silty, pyritic plant debris, resin.
27)	150.80 - 157.00	Shale, medium gray, silty, argillaceous, less carbonaceous than no. 26.
28)	157.00 - 163.50	Shale, same as no. 27.
29)	163.50 - 176.00	Carbonaceous shale, very dark gray, silty to argillaceous, few grains of resin, cuttings are generally very fine, no plant debris noted.
30)	176.00 - 180.86	Carbonaceous shale, silty to argillaceous, pyritic, dark brown, resinous.
31)	180.86 - 185.30	Shale, mostly silty, medium-gray, moderately carbonaceous, a few resin grains.
32)	185.30 - 187.00	Siltstone, light to medium-gray, few pyrite grains, some finely comminuted plant debris, some large pyrite cubes.
33)	187.00 - 189.30	Carbonaceous shale, cuttings very fine,, dark-brown, no plant debris noted, resinous, pyritic; and siltstone, medium-gray.

34) 189.30 - 191.50 Shale, medium-gray, argillaceous to silty.

35) 191.50 - 209.30 Claystone, lght gray, silty, few carbonaceous films, few chips of very fine-grained sandstone with carbonaceous laminae.

36) 209.30 - 210.68 Shale, medium-gray, argillaceous, slightly silty, scattered carbonaceous debris, some pyrite. Few chips with abundant carbonaceous debris on bedding planes, 80 pct siltstone, 20 pct fine- to coarse-grained sandstone, mostly quartz, few kaolinite grains.

37) 210.68 - 213.50 Sandstone, medium- to coarse-grained, subangular, mostly quartz, relatively clean, a few dark minerals, possibly some detrital glauconite. Few lithic fragments, few pyrite grains both probably from higher up. Contains a few angular subhedral quartz grains and generally appears immature. Finer fraction may be washed out.

38) 213.50 - 221.50 Claystone, medium gray, few pyritic, scattered finely comminuted plant debris noted, but chips are very small.

39) 221.50 - 224.80 Claystone, light gray, silty, sample appears to be contaminated from above.

40) 224.80 - 240.86 Sandstone, medium- to coarse-grained, subrounded to subangular, contains clay, possibly kaolinite coatings, fairly clean, few dark grains present.

41) 240.86 - 244.30 Sandstone, same as no. 40, except contains about 20 pct shale chips - some possibly glauconitic (contamination?).

42) 244.30 - 250.80 Sandstone, medium- to coarse-grained, subrounded to subangular, clean, few dark minerals.

43) 250.80 - 252.75 Sandstone, dark gray, medium- to coarse-grained. Grains are coated with clay or drilling mud. Contains abundant shale chips including possibly some glauconite. Contains a few chips of kaolinite. Sample appears to be contaminated from above.

44) 252.75 - 264.86 Sandstone, medium- to coarse-grained, subrounded to subangular. Grains coated with white clay, possibly kaolinite. Almost all quartz. Free from contamination.

45) 264.86 - 274.50 Sandstone, same as no. 44.

46) 274.50 - 284.30 Sandstone, same as no. 44. Few lithic fragments and siltstone chips.,

47) 284.30 - 286.30 Sandstone, same as no. 44 except sample contains sand grains embedded in clayey matrix which appears to be drilling mud. Some milky quartz observed.

48) 286.30 - 287.30 Sandstone. Same as no. 47.

49) 287.30 - 289.30 Sandstone, white, very fine grained, mostly quartz, few percent dark minerals, few siltstone chips. Fine sand may be a constituent of the drilling mud (?) noted in overlying samples.

50)	289.30 - 291.50	Sandstone, same as no. 49. Also contains shale chips and mud welded quartz sand.
51)	291.50 - 294.80	90 pct sandstone, fine grained, white, mostly quartz, few dark minerals, 10 pct shale, chocolate brown, slightly carbonaceous.
52)	294.80 - 297.80	Sandstone, same as above, less carbonaceous material.
53)	297.80 - 300.86	Sandstone, same as above, only a few chips of carbonaceous material.

-END-

Lithologic log: Drill hole TH-6

Drilled by: Sind Arid Zone Development Authority (SAZDA)
Location: Approx. 25°04'N, 70°15'E, in front of rest house, Chachro Village
Total depth: 300.85 m
Cored intervals: none
Lithology logged by: Shafique A. Khan and Altaf H. Chandio (GSP) 12 June through 1 July 89

(note: each unit refers to an interval of samples that were bagged and as a discrete lithologic unit by SAZDA geologists prior to USGS/GSP inspection)

Thickness (m)	Description of cuttings
1) 0.00 - 1.50	Sand, grayish-orange 10YR7/4 to moderate-yellowish-brown 10YR5/4, clean, mostly fine-grained, few medium-grained, subangular to subrounded, mostly quartz - some iron-stained, 15 pct dark minerals, few calcite grains.
2) 1.50 - 15.50	Sand, same as no.1, few coarse grains.
3) 15.50 - 20.00	Sand, grayish-orange 10YR7/4, moderate-yellowish-brown 10YR5/4, fine- to coarse-grained, poorly sorted, fine grains subangular to subrounded, coarse grains rounded, mostly quartz - some iron-stained, 15 pct green to dark-green grains, few calcite grains, few lithic sandstone chips.
4) 20.00 - 23.80	Sand, yellowish-gray 5Y8/1, grayish-orange 10YR5/4, moderate-yellowish-brown 10YR5/4, calcareous, lithic sandstone chips.
5) 23.80 - 29.30	Sand, greyish-orange 10YR7/4, fine- to medium-grained, mostly fine-grained, moderately sorted, subrounded to subangular, mostly quartz - some iron-stained, few calcite grains.
6) 29.30 - 32.80	Sand, same as no. 5, few rounded quartz grains.
7) 32.80 - 38.30	Sand, same as no. 6.
8) 38.30 - 40.00	Clay, light-brown 5YR6/4, sandy - possible contamination from above.
9) 40.00 - 44.50	Clay, same as no. 8, few calcareous lithic fragments.
10) 44.50 - 55.40	Clay, moderate-yellowish-brown 10YR5/4, few calcareous lithic fragments, sparse mica.
11) 55.40 - 65.80	Clay, same as no. 10 ??
12) 65.80 - 69.30	Limestone gravel, mostly calcareous lithic fragments, few quartz grains, argillaceous.
13) 69.30 - 78.85	Clay, grayish-orange, 10YR7/4, with calcareous lithic fragments and quartz grains.

14) 78.85 - 80.50 Clay, moderate-orange-pink 5YR8/4, few calcareous lithic fragments and quartz grains.

15) 80.50 - 84.30 Clay, moderate-orange-pink, 5YR8/4, silty.

16) 84.30 - 98.80 Clay, moderate-orange-pink, 5YR8/4, silty, sandy.

18) 98.80 - 105.50 Clay, moderate-orange-pink, 5YR8/4, silty, sandy, contains coarse rounded quartz grains and calcareous and noncalcareous lithic fragments.

19) 105.50 - 108.85 Clay, moderate-yellowish-brown, 10YR5/4, silty, sparse quartz grains.

20) 108.85 - 119.30 Clay, moderate-yellowish-brown, 10YR5/4, few calcareous and noncalcareous lithic fragments, few rounded coarse quartz grains.

21) 119.30 - 126.85 Clay, variegated brown, yellow, red, and gray, few calcareous lithic fragments.

22) 126.85 - 144.85 Clay, variegated brown, maroon, yellow, and gray, slightly calcareous.

23) 144.85 - 156.85 Clay, variegated, silty, sandy, few calcareous and noncalcareous lithic fragments.

24) 156.85 - 161.50 Sand, moderate-reddish-orange 10R6/6, moderate reddish brown 10R4/6, silty, very fine to fine-grained, subangular, few rounded coarse grains, with white to cream-colored calcareous lithic fragments, sample is oxidized.

25) 161.50 - 166.30 Sand with lithic fragments, similar to no.24 except lighter, colored orange-pink 5YR7/2 and grayish-orange 10YR7/4, less iron oxides, a few maroon and pink spots.

26) 166.30 - 170.80 Sand, pinkish-gray 5YR8/1 and white N-9, a few yellow and maroon oxidation spots, very fine to fine-grained, subangular, a few subrounded to rounded coarse grains, slightly calcareous, a few calcareous lithic fragments.

27) 170.80 - 174.30 Sand, grayish-orange-pink 5YR7/2, slightly silty, mostly coarse- to very coarse grained, subangular to subrounded, few calcareous white and cream-colored lithic fragments.

28) 174.30 - 178.80 Sand, very pale orange 10YR8/2, few yellow and brown iron oxide spots, mostly very fine to fine-grained, subangular quartz, few rounded to subrounded coarse grains, slightly calcareous and argillaceous, few angular white to cream colored lithic fragments.

29) 178.80 - 182.30 Sand, pale yellow orange 10YR8/6, mostly coarse- to very coarse-grained, rounded to subrounded quartz, few fine-grained subangular grains, sparse white to cream-colored lithic fragments.

30) 182.30 - 192.00 Sand, light-brown 5YR6/4 and moderate-yellowish-brown 10YR5/4, oxidized, fine- to coarse-grained, subangular to rounded, argillaceous, slightly calcareous, few calcareous lithic fragments.

31) 192.00 - 201.85 Sand, very fine grained, few coarse grains, argillaceous, few oxidized yellow and maroon spots.

32) 201.85 - 206.50 Clay, variegated light-gray N7, yellow, brown, red, and maroon spots, medium- to coarse-grained quartz, sparse muscovite flakes.

33) 206.50 - 209.30 Sand, medium-light-gray N6, argillaceous, fine- to coarse-grained, coarse grains rounded to subrounded.

34) 209.30 - 213.80 Sandstone, light-olive-gray 5Y6/1, few hard red and maroon cuttings, mostly very coarse to coarse-grained quartz, few calcareous lithic fragments, few claystone cuttings, probably from above.

35) 213.80 - 215.30 Sandstone, mostly medium- to coarse-grained, subrounded to rounded quartz grains, with light-olive-gray to dark gray claystone, black pyritic claystone fragments, possibly carbonaceous.

36) 215.30 - 219.50 Claystone, olive-gray to dark-gray, disseminated pyrite and carbonaceous material, with coarse rounded quartz grains and a few white and cream-colored lithic fragments.

37) 219.50 - 221.80 Claystone, same as no.36 but contains glauconite and is less sandy.

38) 221.80 - 228.85 Shale, olive black 5Y2/1, contains carbonaceous material, disseminated pyrite and glauconite, well developed crystalline pyrite in places.

39) 228.85 - 237.30 Shale, olive black 5Y2/1, slightly sandy and silty, carby streaks, glauconite grains, disseminated and crystalline pyrite, sparse resin.

40) 237.30 - 240.40 Shale, same as no. 39.

41) 240.40 - 240.80 Carbonaceous shale.

42) 240.80 - 242.80 Shale, same as no. 39.

43) 242.80 - 244.60 Shale, same as no. 39, glauconite is rounded, few calcareous lithic fragments - probably contamination.

44) 244.60 - 249.20 Dirty coal, brownish-black 5YR2/1, silty, sandy, disseminated pyrite, scattered resin.

45) 249.20 - 249.80 Shale.

46) 249.80 - 252.10 Coal, same as no.44.

47) 252.10 - 258.00 Shale, brownish-black, 5YR2/1, silty, sandy, coaly and carby streaks, disseminated pyrite grains, few resin specks.

48) 258.00 - 258.40 Carbonaceous shale.

49) 258.40 - 261.00 Shale, same as no. 47.

50) 261.00 - 261.60 Carbonaceous shale.

51) 261.60 - 264.60 Shale, same as no. 47.

52) 264.60 - 269.40 Shale, brownish-black 5YR2/1, olive-black 5Y2/1, coaly and carbonaceous streaks, few resin specks.

53) 269.40 - 271.80 Coal.

54) 271.80 - 274.10 Shale, same as no. 52.

55) 274.10 - 274.60 Coal, disseminated pyrite and scattered specks of resin.

56) 274.60 - 276.85 Shale, same as no. 52.

57) 276.85 - 290.50 Shale

58) 290.50 - 296.10 Shale.

59) 296.10 - 298.80 Coal.

60) 298.80 - 299.30 Shale.

61) 299.30 - 299.70 Carbonaceous shale.

62) 299.70 - 300.85 Sandstone, medium- to coarse-grained, subangular to rounded, poorly sorted, mostly quartz.

-END-

Appendix 8

Geophysical logs: drill holes TH-5 and TH-6

TH-5

1)	Open-hole gamma/neutron/resistivity:	0 - 302 m	p. 2 - 16
2)	Open-hole gamma-gamma (4 pi) density:	120 - 200 m	p.17 - 22
3)	Open-hole 3-arm caliper:	120 - 200 m	p.23 - 27

TH-6

4)	Open-hole gamma/neutron:	0 - 300 m	p.28 - 43
5)	Open-hole gamma-gamma (4 pi) density:	0 - 300 m	p.44 - 59

EXPLANATION OF SYMBOLS APPENDED TO LOGS
(in part supplemented from cuttings)

Fine-grained quartz

Coarse-grained to granule quartz

Clay

Silt

Carbonaceous shale/coal

Lithic limestone fragments

Ironstone cuttings

Kaolinite

Glauconite

Pyrite

Shell debris

Plant fragments

Disseminated carbonaceous material

Caving

Coal (?) pick

USGS

GEOSCIENCE ASSOCIATES

HOLE NUMBER: TH-5 (SAZDA)

DATE: 19th March, 1989.

LOCATION

STATE/COUNTY	Sind Pakistan		
REGION	Dhakla, Thar ParKar.		
PROJECT	SAZDA (Ground Water)		
PROSPECT			
SEC.	TWP.		RNG.

TYPE	GAM		Neutron	
LOGGED DEPTH	300m		302m	
RANGE (f.s.)	100		1K	
%STD DEV	3%		1%	
PAPER SPEED	1-1		1-1	
LOG SPEED	6-1		6-1	
BKGND. COUNT				
PROBE NO.	GN-1		GN-1	
SIZE (dia.) (in)	1 3/8"		1 3/8"	
K-FACTOR				
DEAD TIME	2		2	
STANDARD				

DIGITAL DATA

PRINT INTERVAL				
TIMEBASE				

DENSITY CALIBRATION

ALUMINUM				
LUCITE				

HOLE DATA

DEPTH DRILLED:	300.86 m		
DEPTH LOGGED:	302 m		
COLLAR ELEV.			
DIA. Sec	FROM	TO	
DIA. Caliper	FROM	TO	
DIA. log	FROM	TO	
BOREHOLE MEDIUM	H_2O + Mud		
FLUID LEVEL	10.2 m		

CASING DATA

WALL SIZE	
I.D.	
CASED FROM	0 TO 1.5m
CASING TYPE	

SAMPLE DATA

NON-CORED HOLE ■ CORED HOLE □

SAMPLED INTERVAL	SAMPLE TYPE

REMARKS

CLIENT

CLIENT	U.S.G.S – G.S.P.
GEOLOGIST:	
UNIT OPERATOR	Muneer Mehtab
UNIT NO. PL-2	OFFICE

ELECTRIC

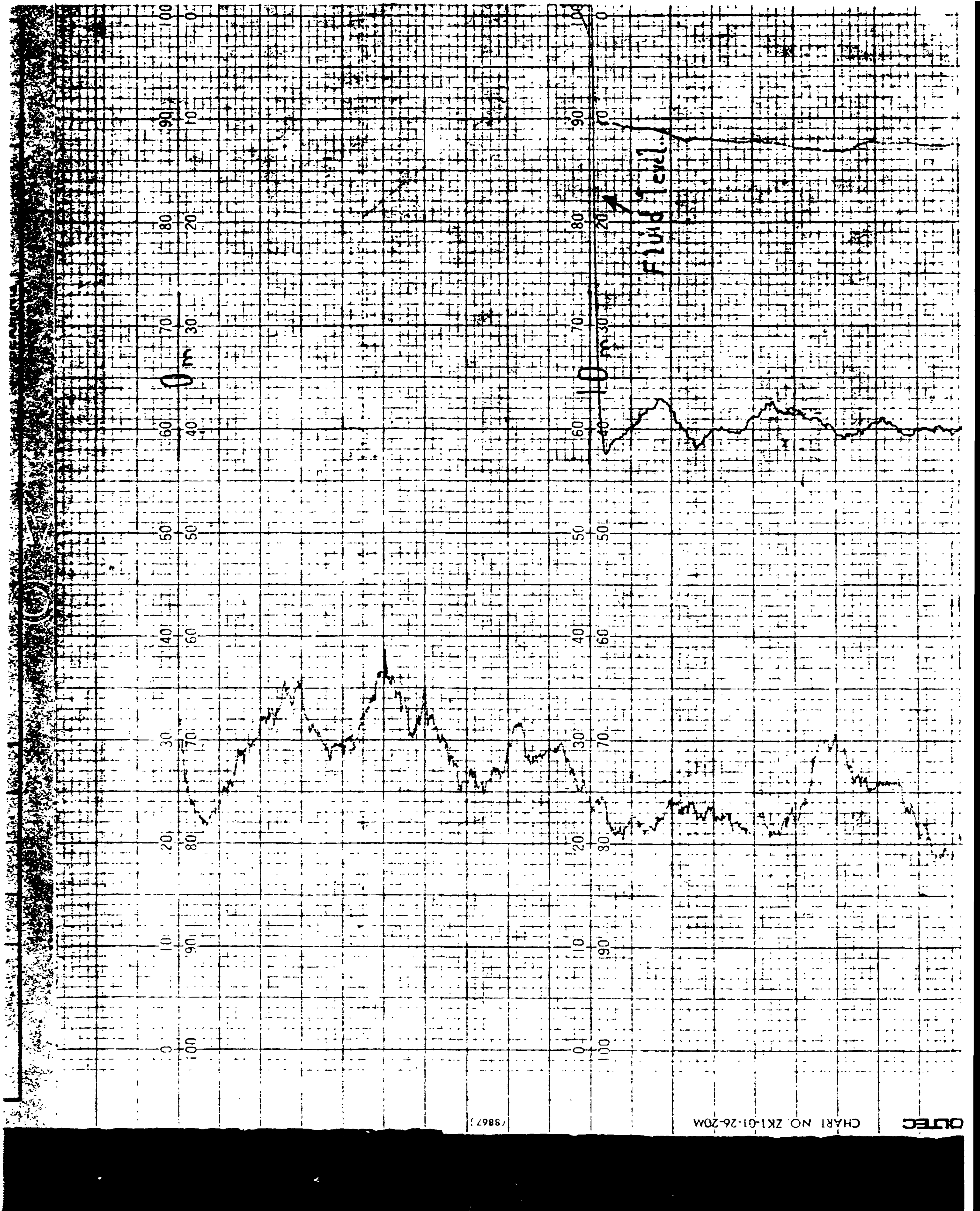
TYPE	RESIST	S.P.
LOGGED DEPTH	300 m	FT
SCALE	10	
PAPER SPEED	1-1	
LOG SPEED	6-1	
FINE ADJ.	1000 Bias	

CALIPER

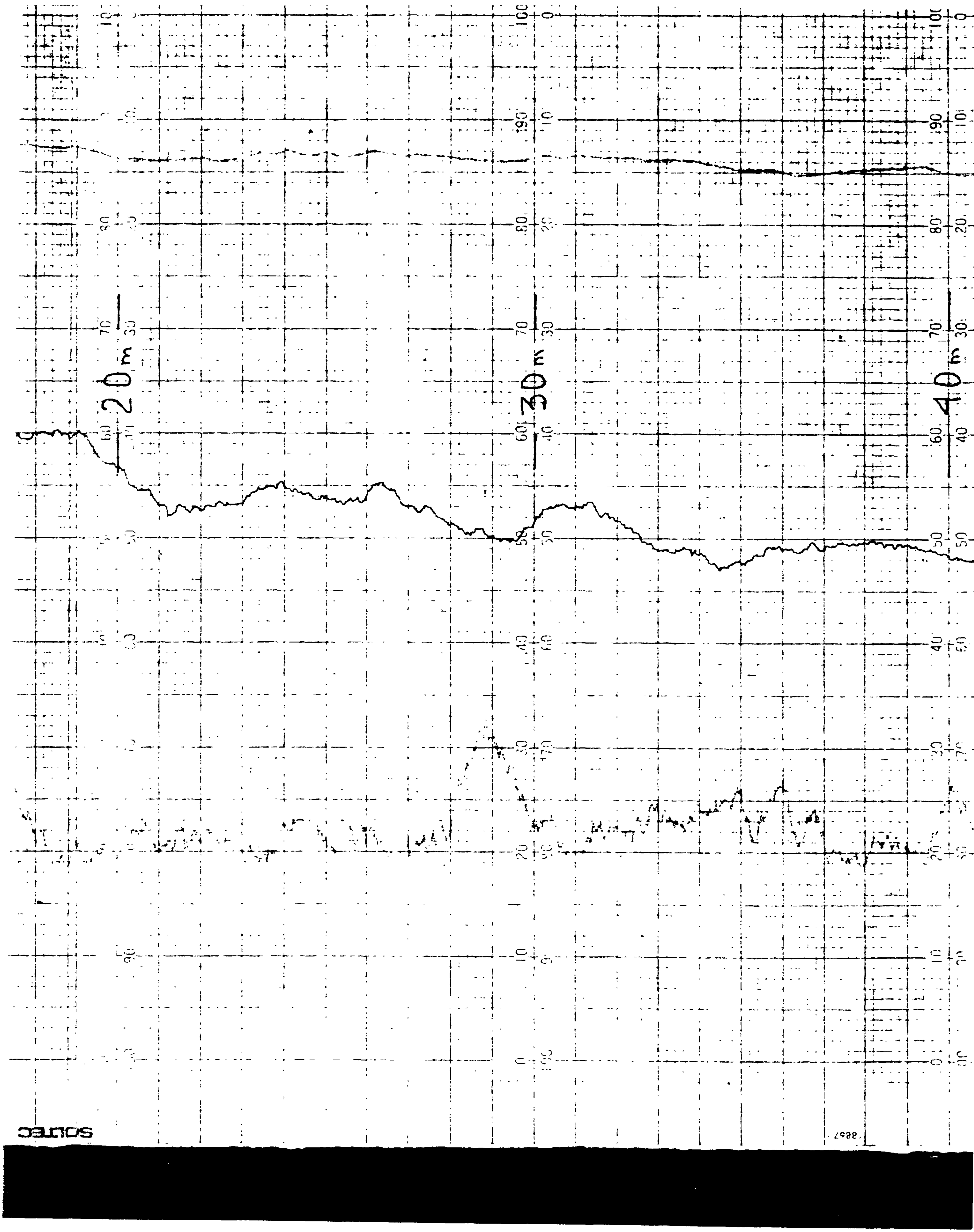
LOGGED DEPTH	FT
SCALE	
PAPER SPEED	
LOG SPEED	
ARM LENGTH	IN
MAX DEF.	IN

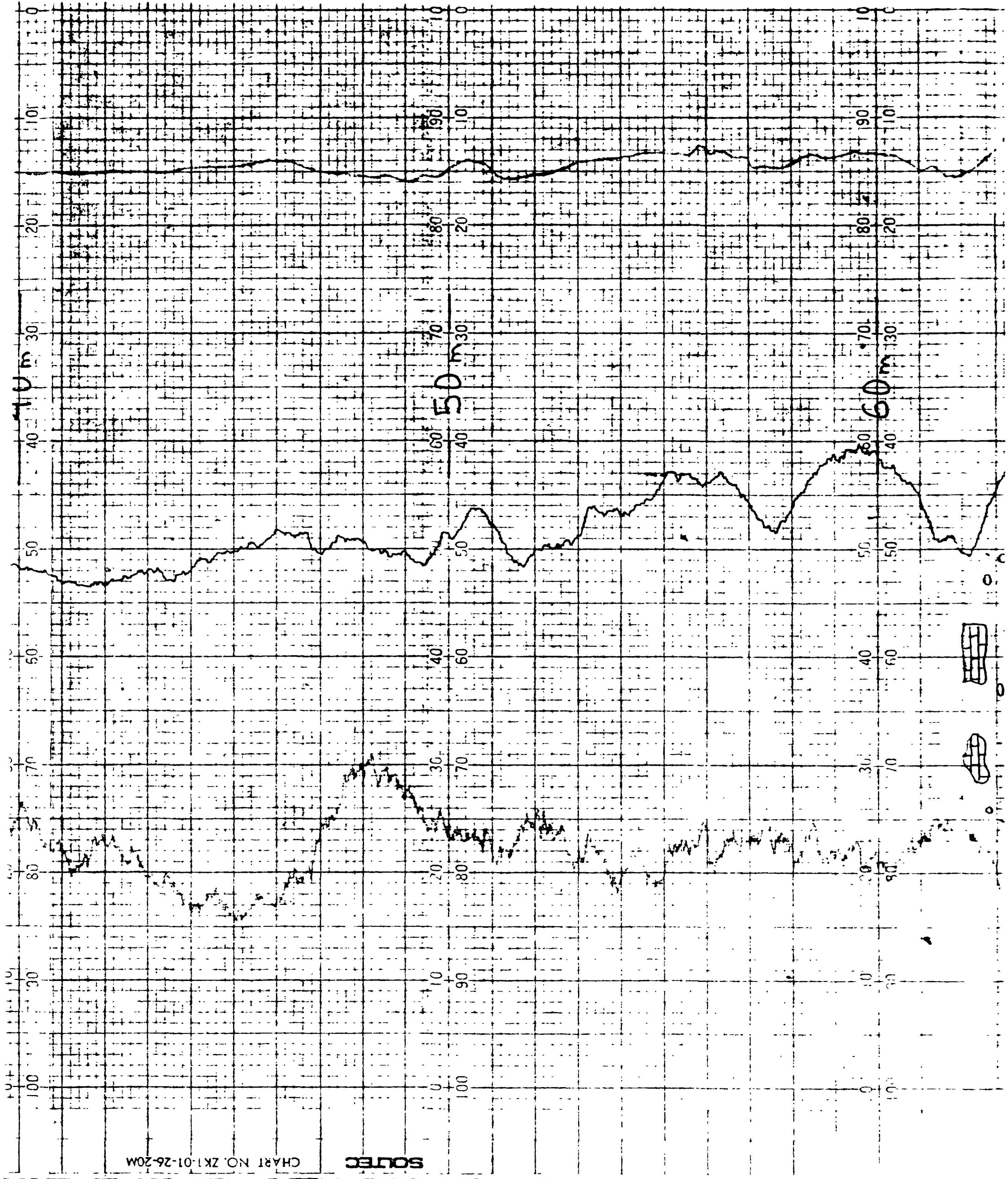
VERTICAL DEV.

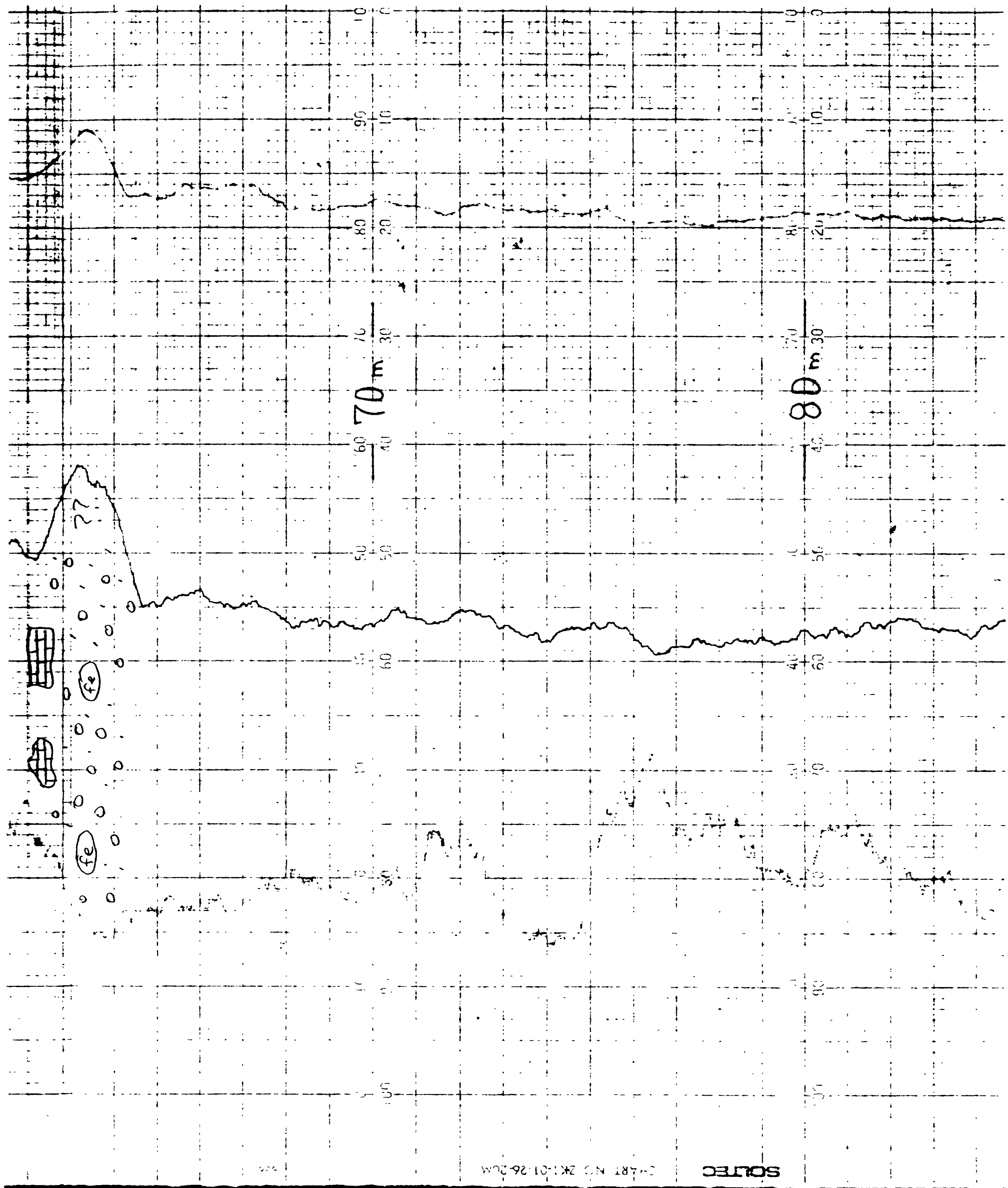
DEPTH					
INCLIN.					
BEARING					

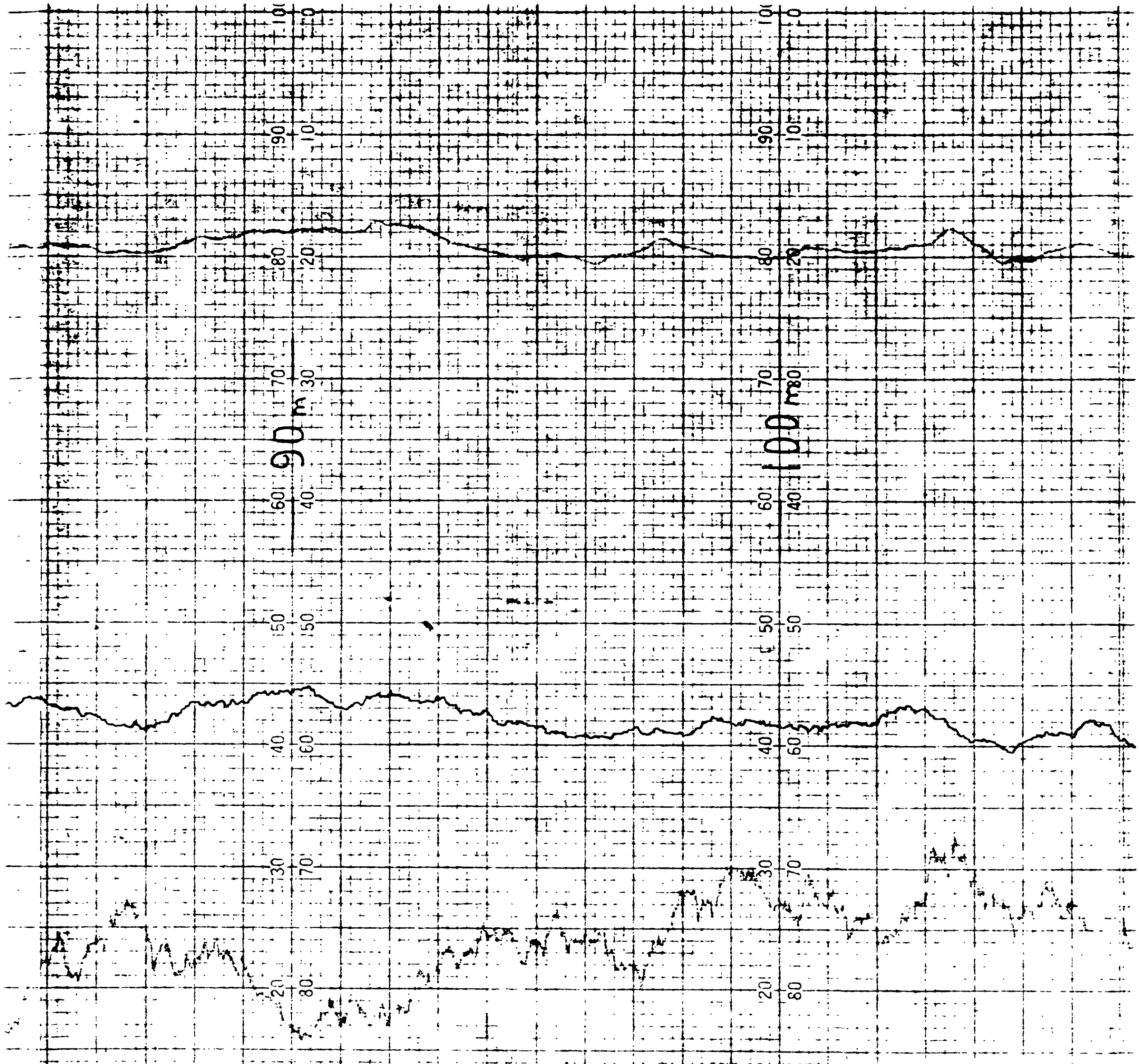


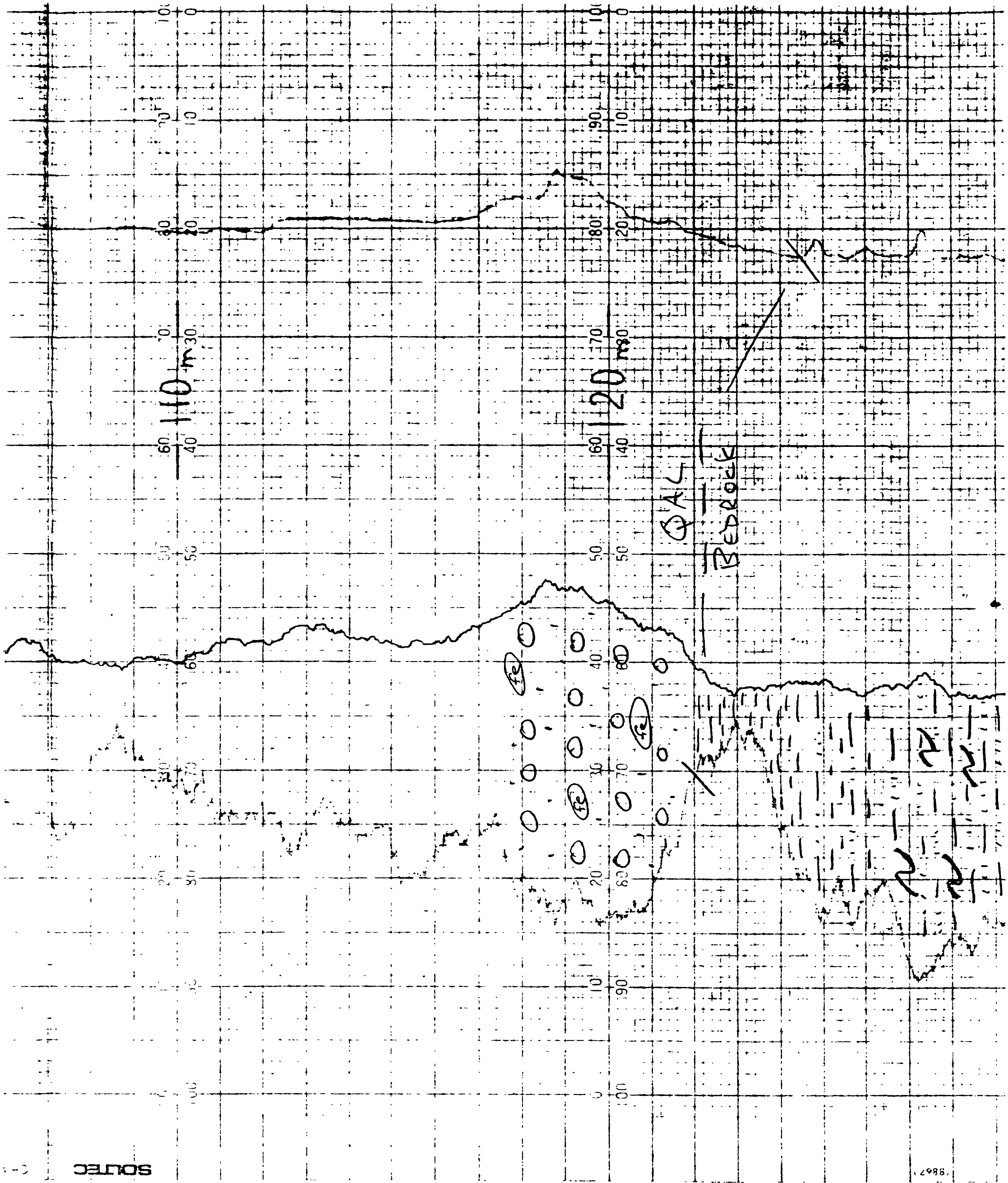
0 m
10 m
Fluid level
CHART NO. ZK1-01-26-20M

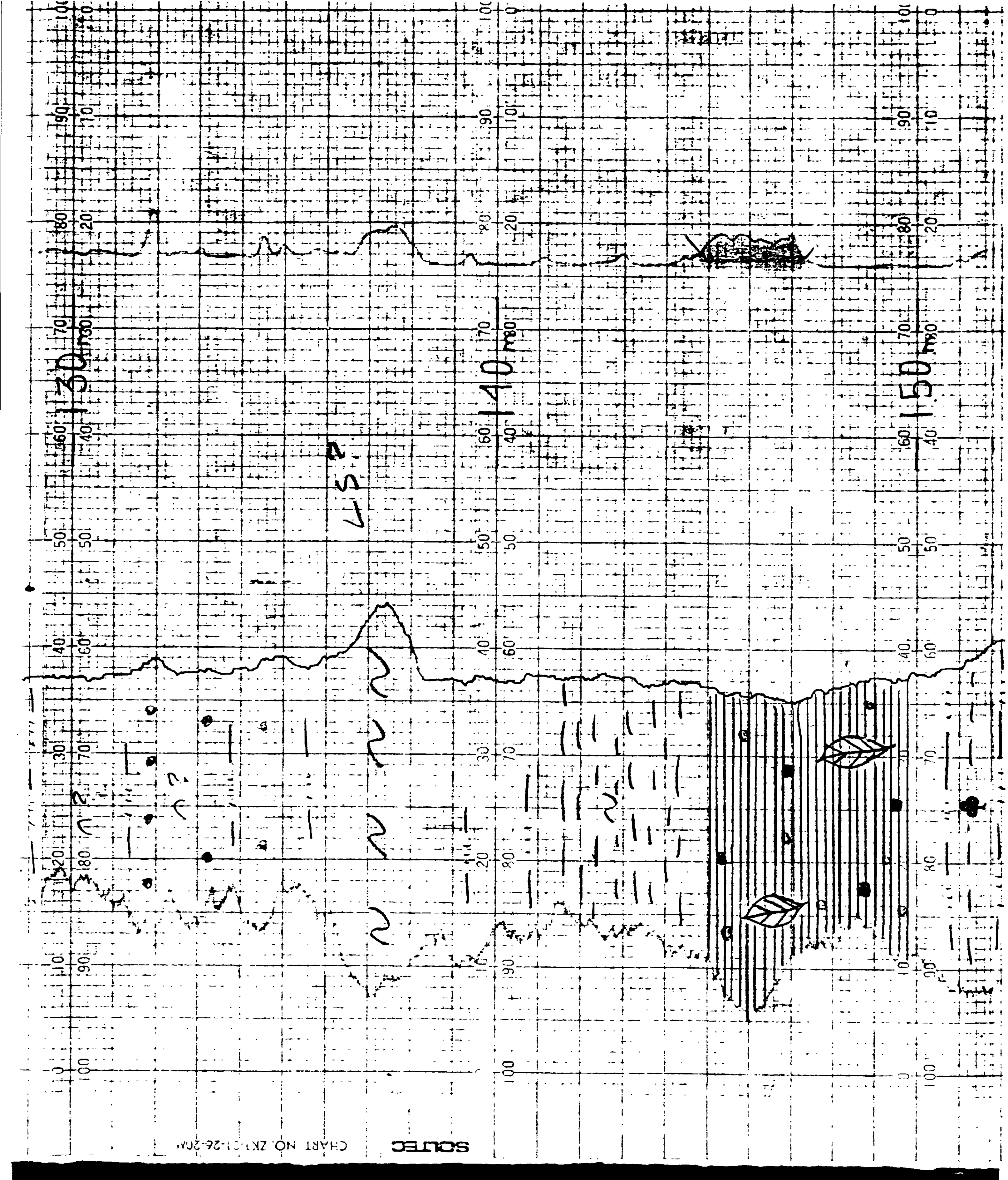

20 m
30 m
40 m

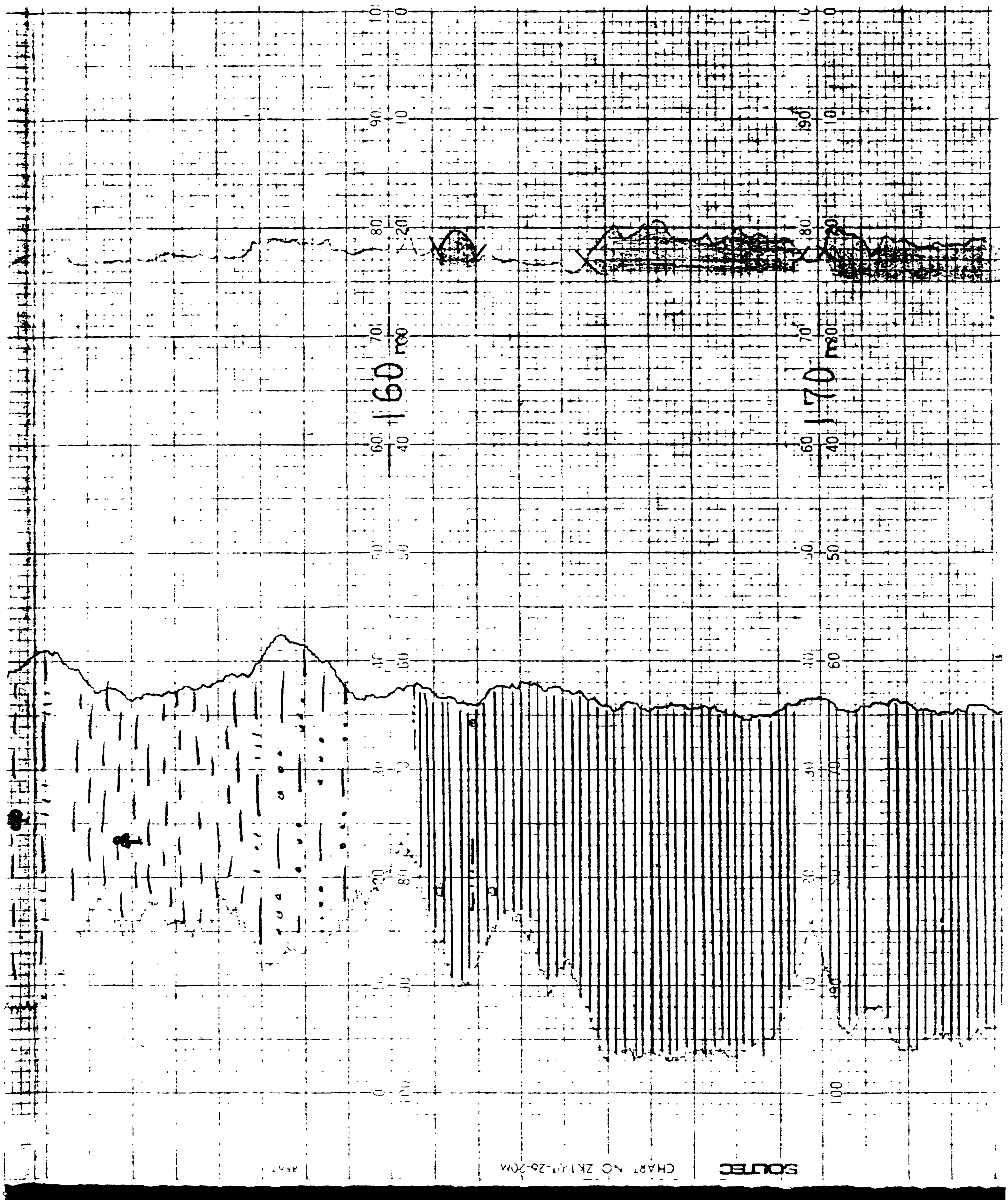

40 m
50 m
60 m
SOLTEC
CHART NO. ZK1-01-26-20M

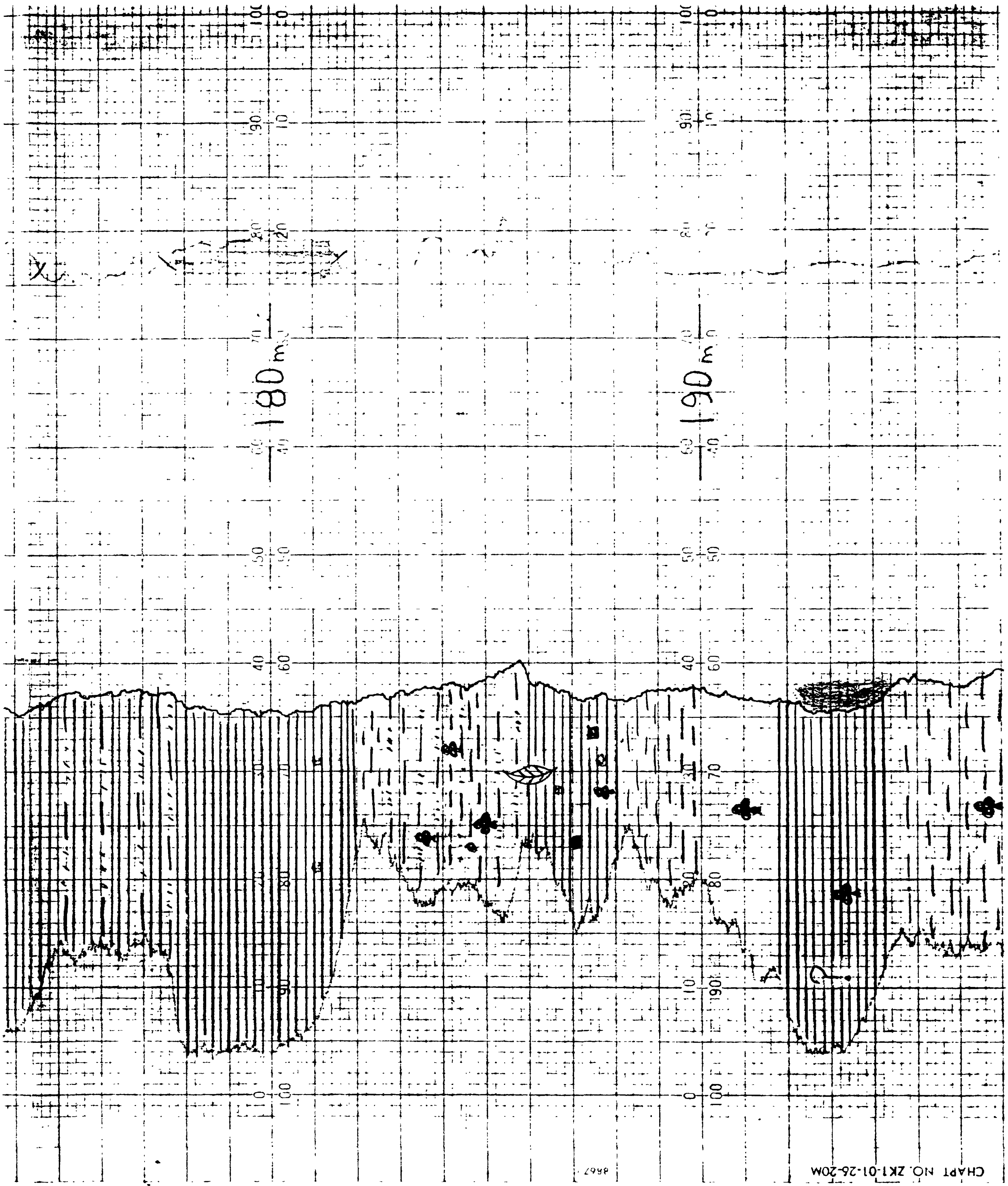

70m
80m
fe
fe
SOLTEC

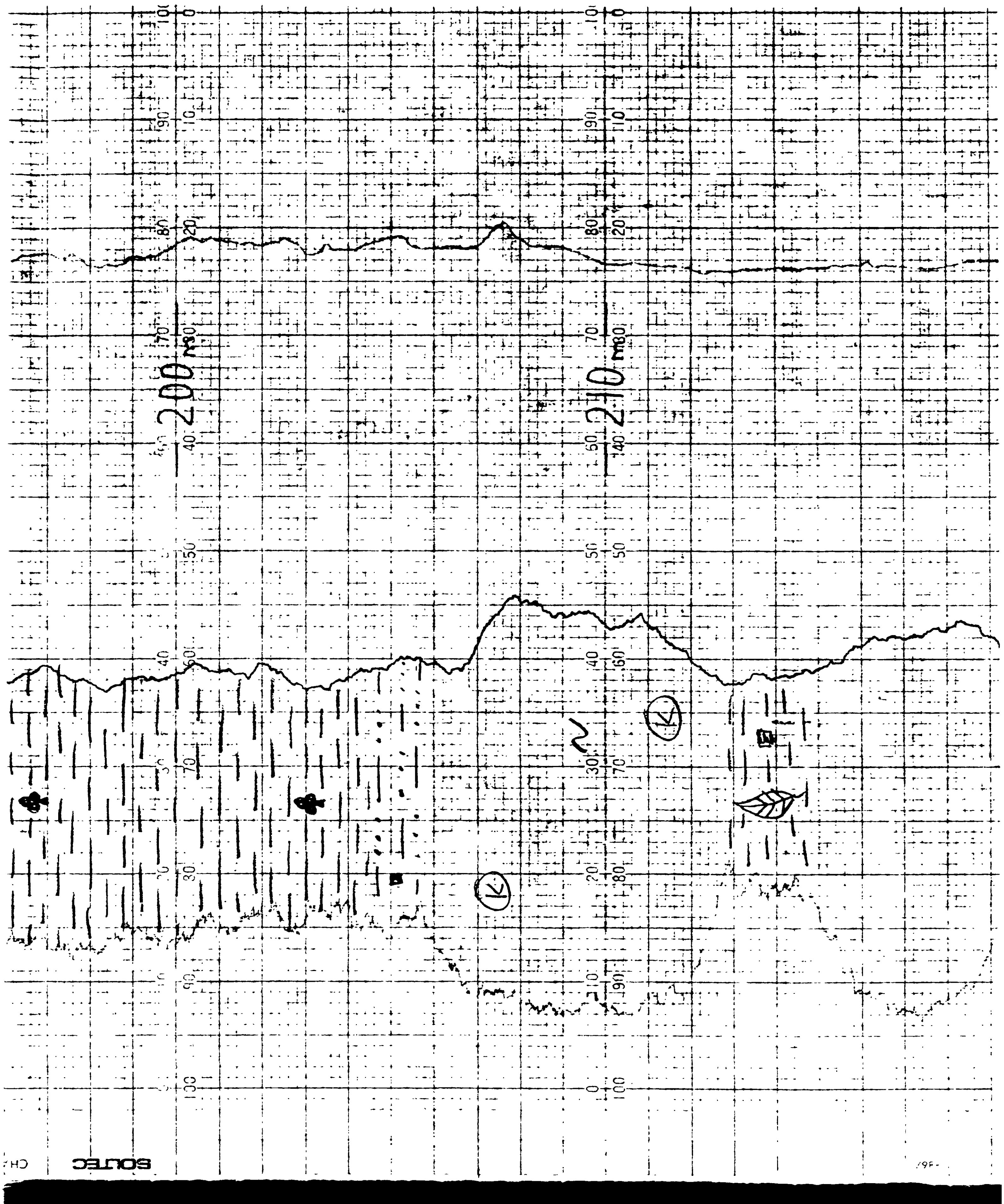

90 m
100 m

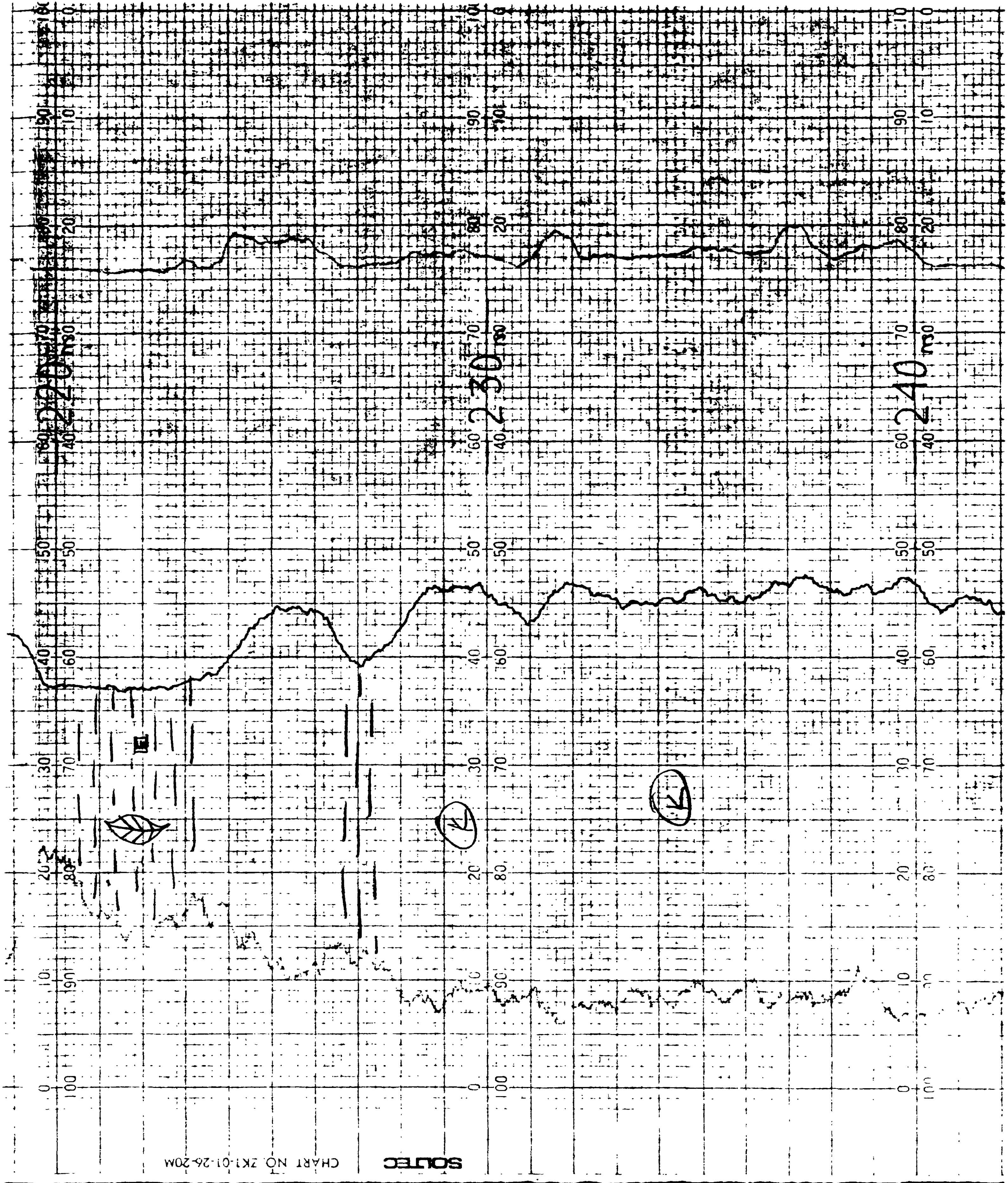

110 m
120 m
QAL
BEDROCK


130m
140m
150m
LS?


160
170


180 m
190 m
CHART NO. ZK1-01-26-20M


200
210



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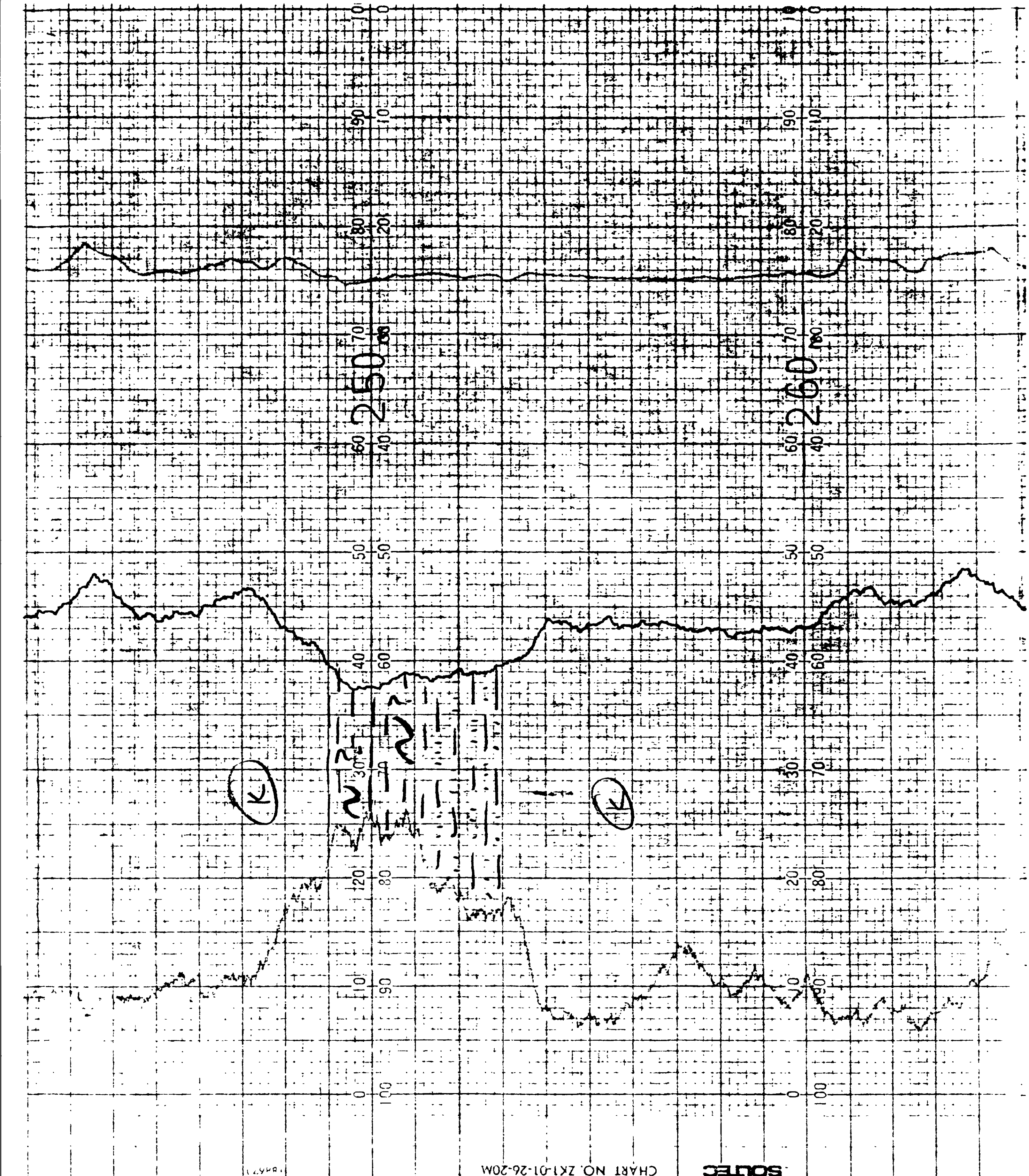
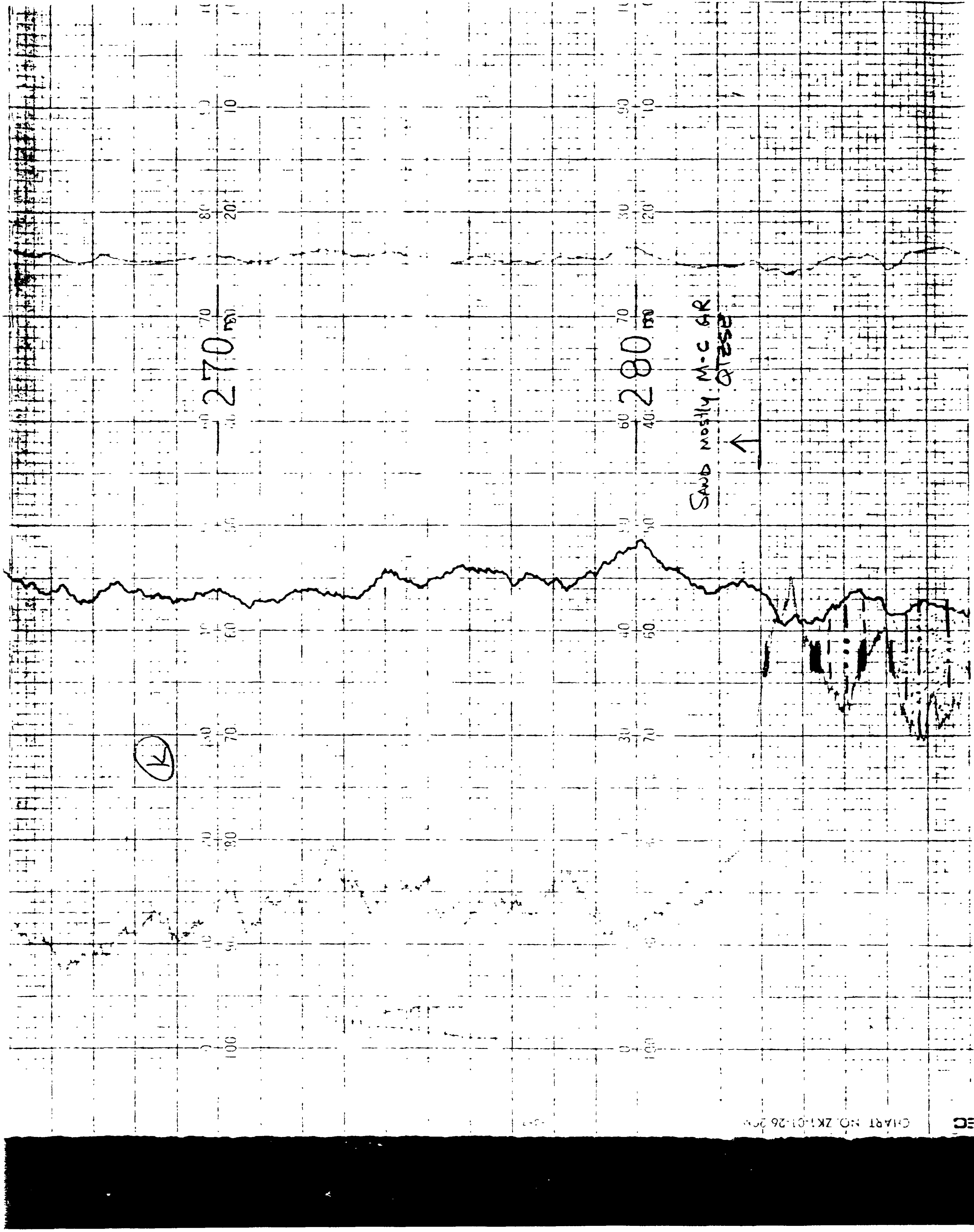
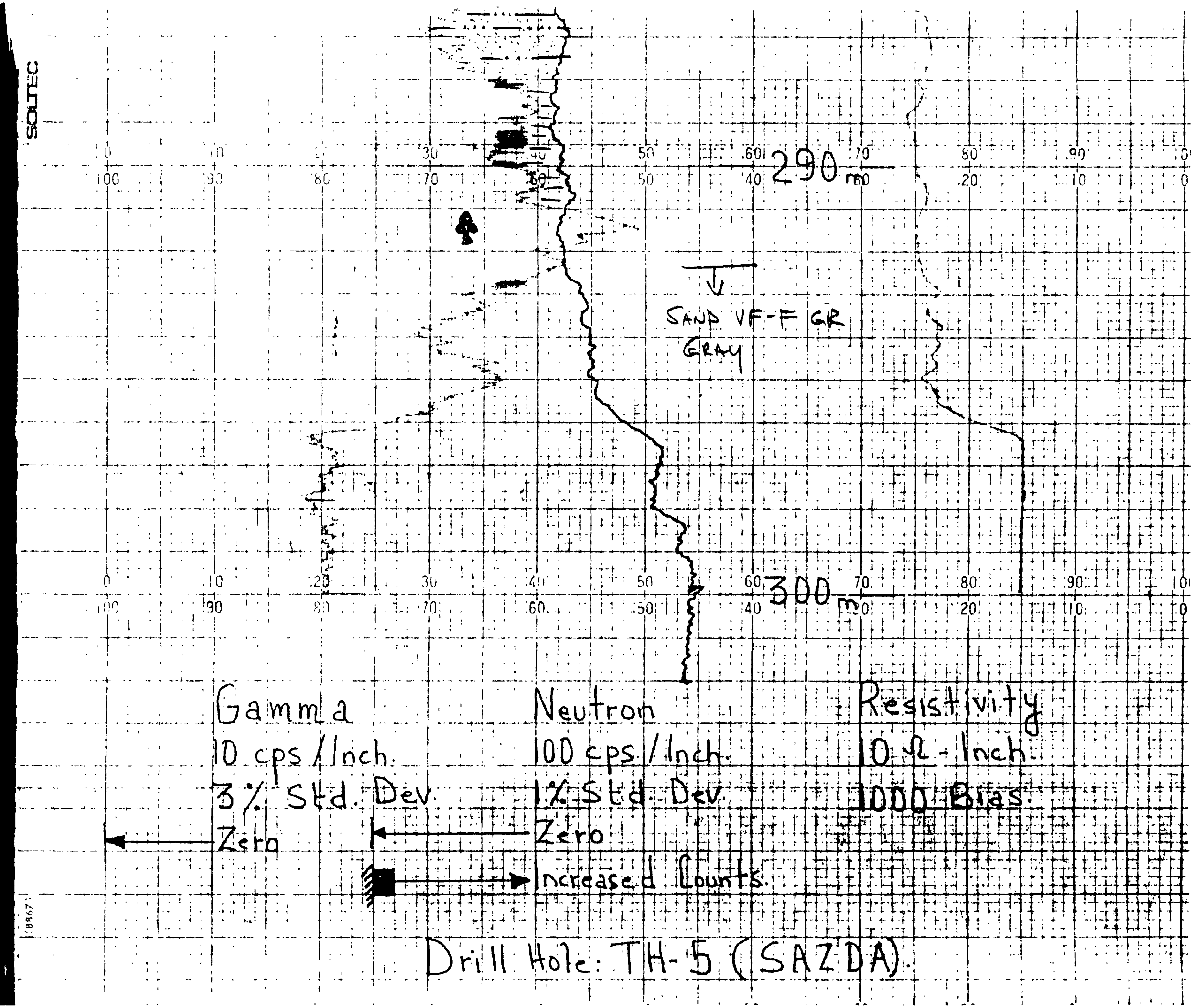

250
260


270 m
280 m
SAND mostly M-C GR


SOLTEC
290 m
300 m
SAND VF-F GR
GRAY
Gamma
10 cps / Inch.
3% Std. Dev.
Zero
Neutron
100 cps / Inch.
1% Std. Dev.
Zero
Increased Counts.
Resistivity
10 Ω - Inch.
1000 Bias.
Drill Hole: TH-5 (SAZDA).
(8867)

USGS

GEOSCIENCE ASSOCIATES

HOLE NUMBER: TH-5 (SAZDA)

DATE: 19th March 1989

LOCATION

STATE/COUNTY	Sind Pakistan		
REGION	Dhakla, Thar Parkar		
PROJECT	SAZDA (Ground Water)		
PROSPECT			
SEC.	TWP.	RNG.	

TYPE	GAM	4 Pi Density	
LOGGED DEPTH		200 m	
RANGE (f.s.)		10K	
%STD DEV		1%	
PAPER SPEED		1-1	
LOG SPEED ft/min		6-1	
BKGND. COUNT			
PROBE NO.		GD-1	
SIZE (dia.) (in)		1 3/8"	
K-FACTOR x10⁻⁵			
DEAD TIME μsec		2	
STANDARD (cps)			

DIGITAL DATA

PRINT INTERVAL			
TIMEBASE sec			

DENSITY CALIBRATION

ALUMINUM			
LUCITE			

HOLE DATA

DEPTH DRILLED	300.86 m		
DEPTH LOGGED	200 m		
COLLAR ELEV.			
DIA. Sec		FROM	TO
DIA. Caliper		FROM	TO
DIA. Mag		FROM	TO
BOREHOLE MEDIUM	H₂O + Mud		
FLUID LEVEL			

CASING DATA

WALL SIZE	
I.D.	
CASED FROM	0 TO 1.5 m
CASING TYPE	

SAMPLE DATA

NON-CORED HOLE ■ CORED HOLE □

SAMPLED INTERVAL	SAMPLE TYPE

REMARKS

CLIENT

CLIENT	U.S.G.S. - G.S.P.
GEOLOGIST	
UNIT OPERATOR	MUJEEB-MEHTAB
UNIT NO.	PL-2 OFFICE

ELECTRIC

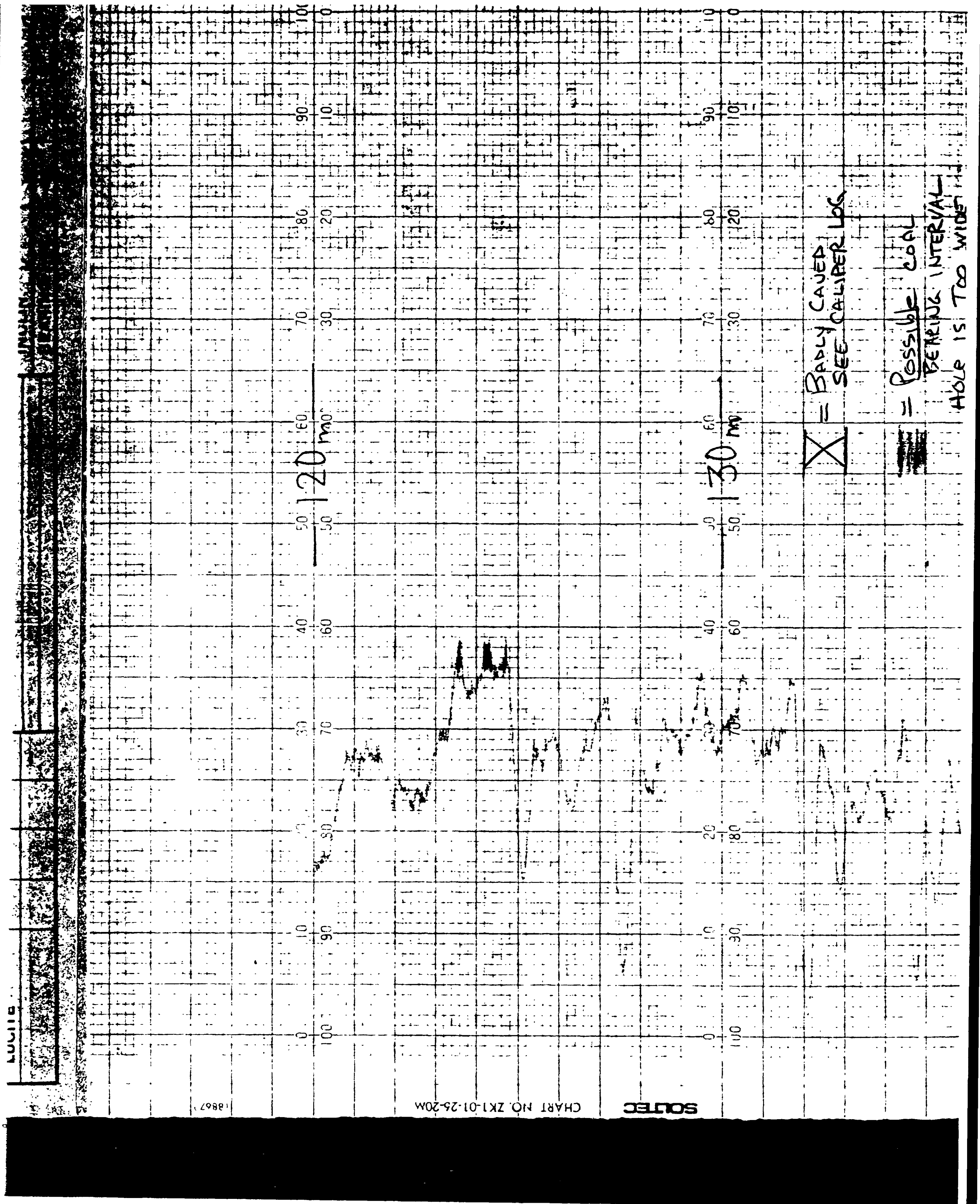
TYPE	RESIST	S.P.
LOGGED DEPTH	FT.	FT.
SCALE		
PAPER SPEED		
LOG SPEED		
FINE ADJ.		

CALIPER

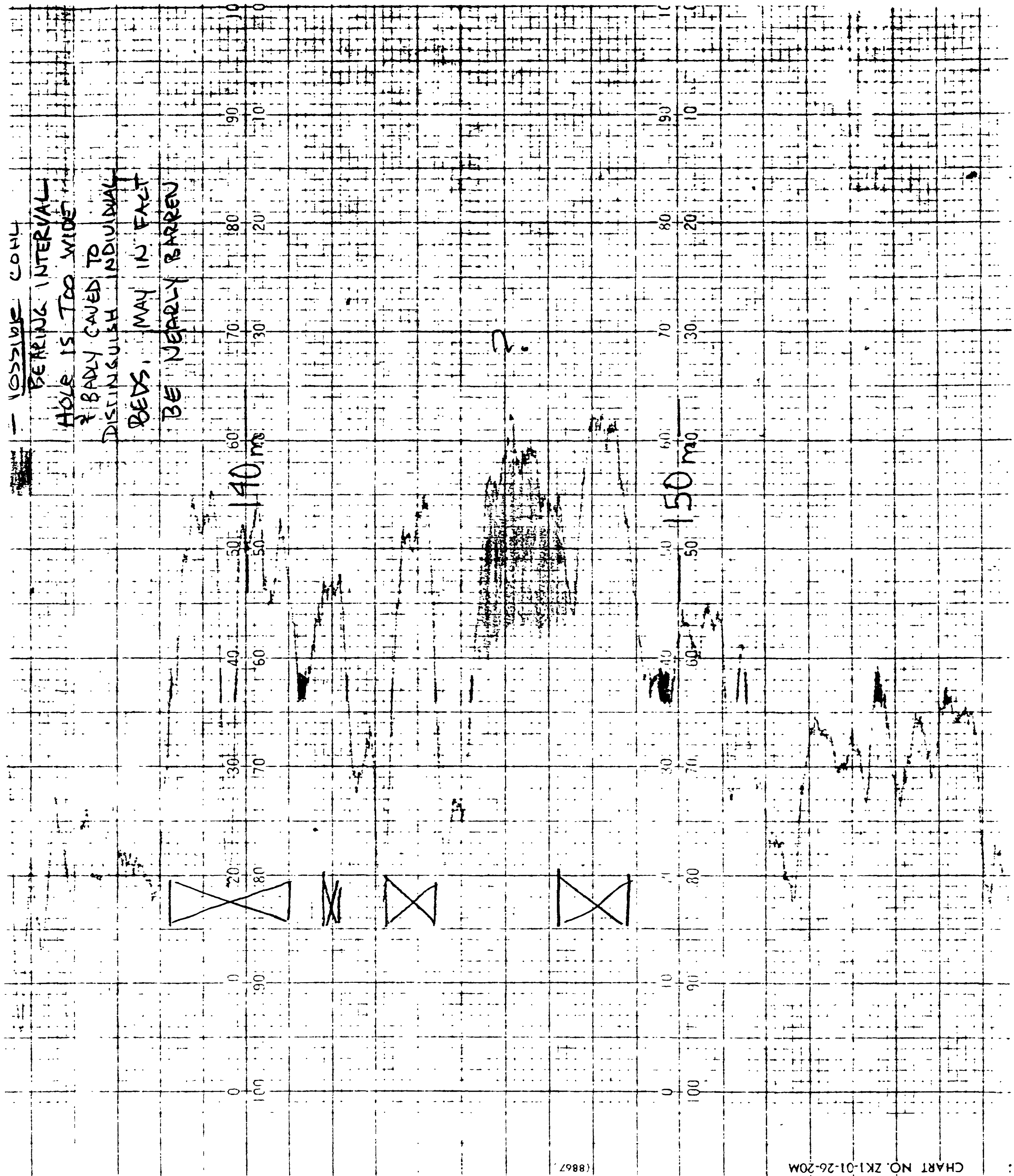
LOGGED DEPTH	FT.
SCALE	
PAPER SPEED	
LOG SPEED	
ARM LENGTH	IN
MAX DEF.	

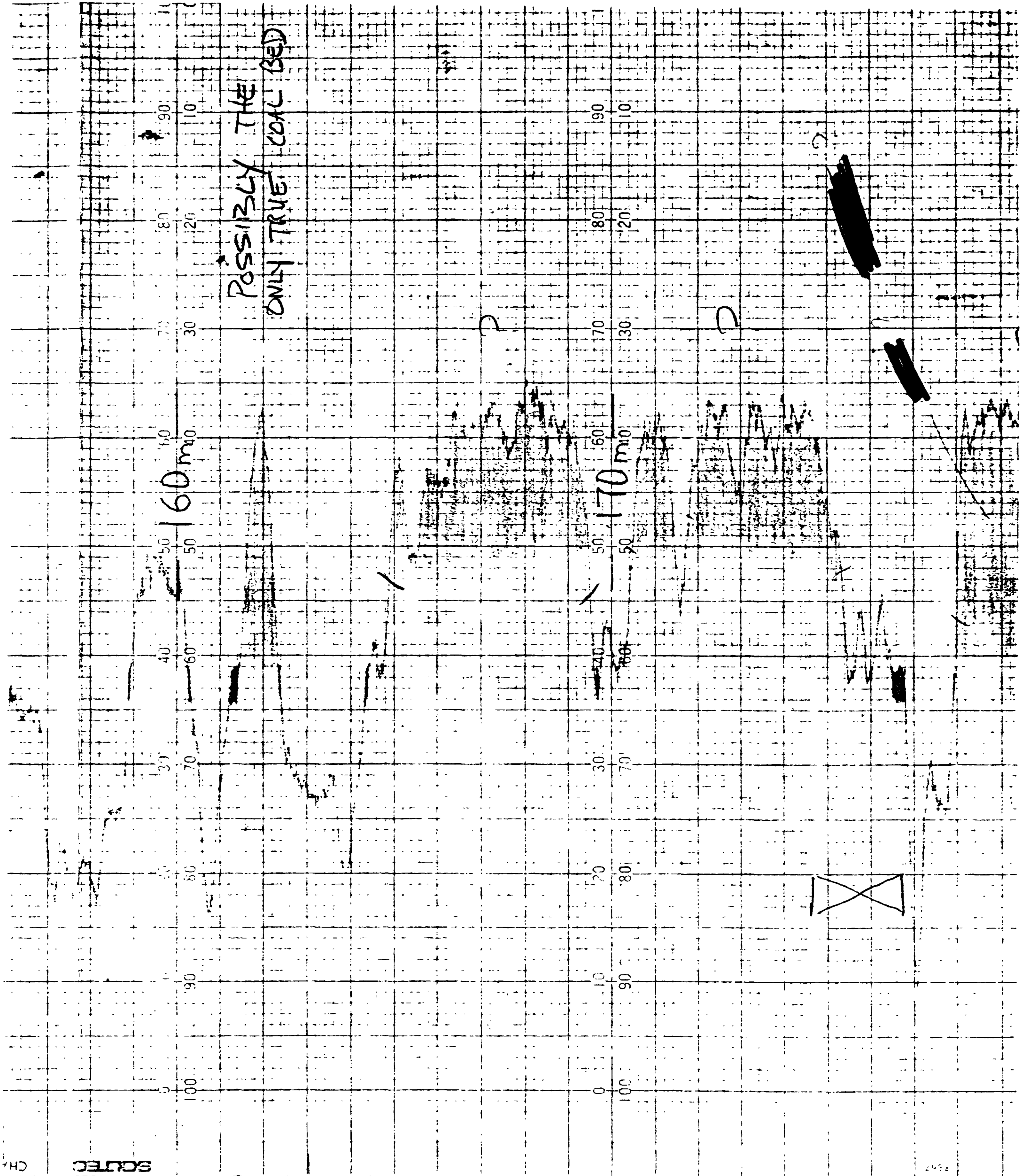
VERTICAL DEV.

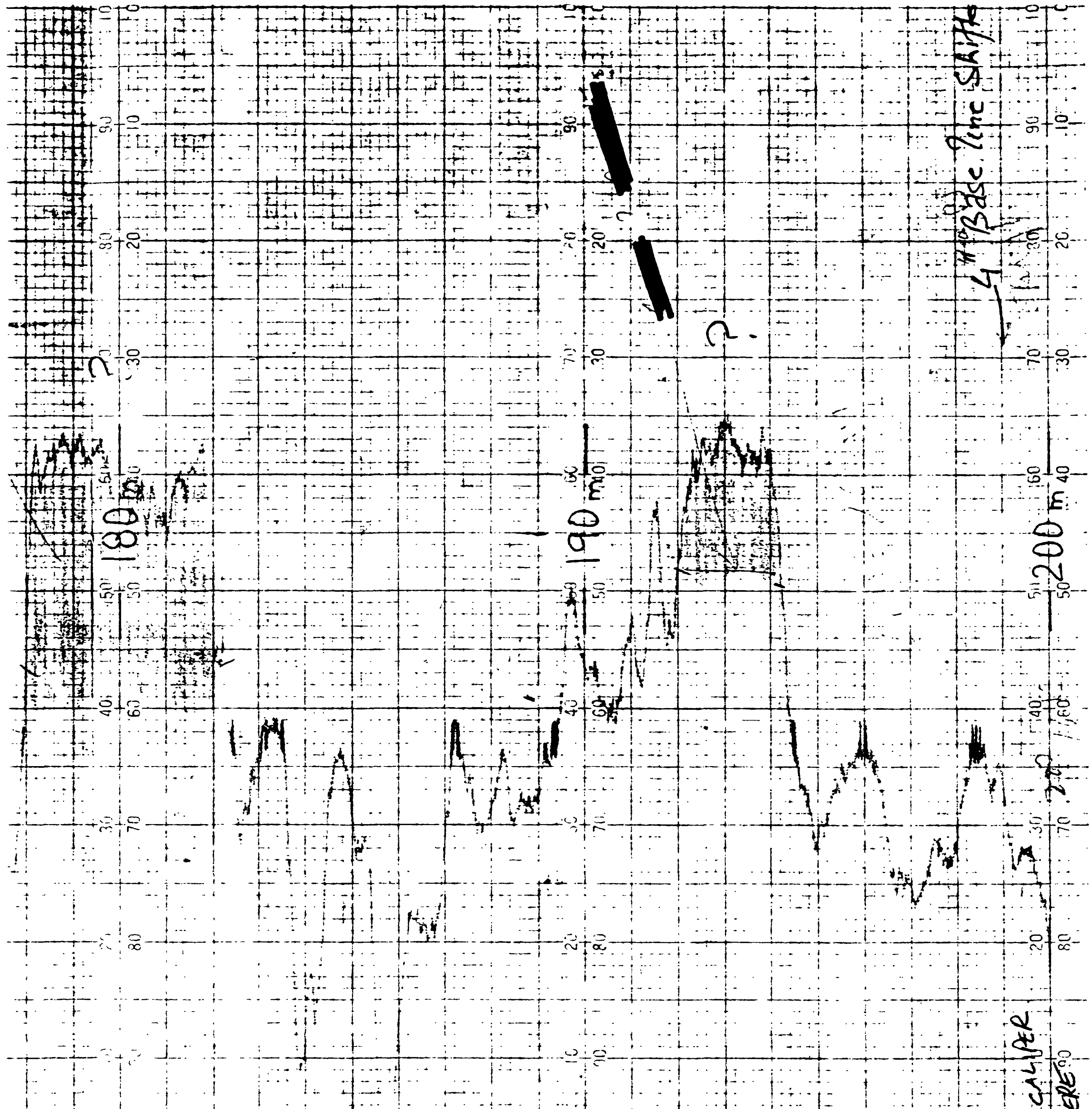
DEPTH				
INCLIN.				
BEARING				



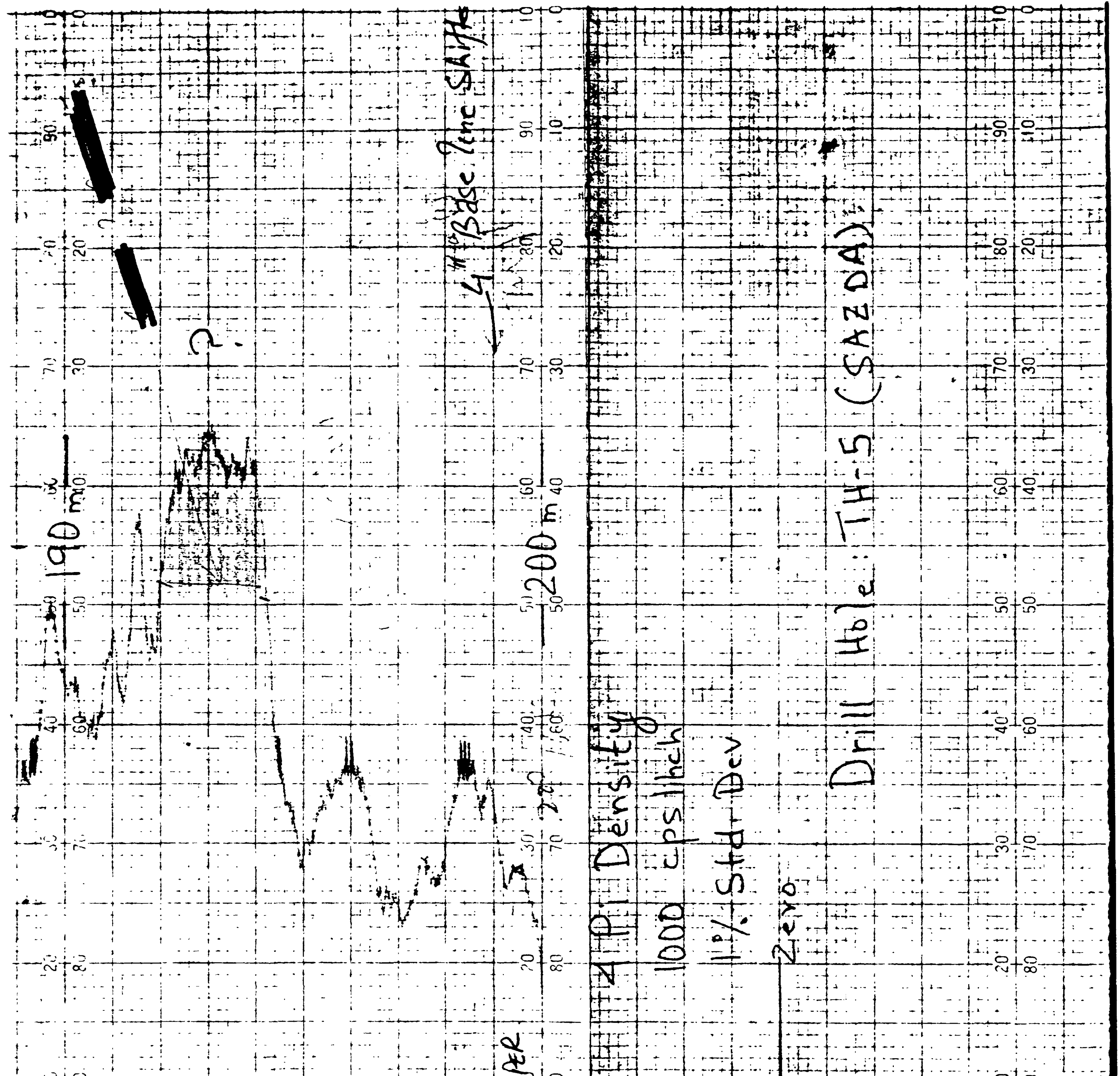
120 mo
130 m
= BADLY CAVED SEE CALIPER LOG
= POSSIBLE COAL BEARING INTERVAL HOLE IS TOO WIDE
CHART NO. ZK1-01-25-20M
SOLTEC


POSSIBLE COAL BEARING INTERVAL
HOLE IS TOO WIDE
? BADLY CAVED TO DISTINGUISH INDIVIDUAL BEDS, MAY IN FACT BE NEARLY BARREN
140 m
150 m
CHART NO. ZK1-01-26-20M


POSSIBLY THE ONLY TRUE COAL BED
160 m
170 m



180 m
190 m
200 m
GOT CALIPER TO HERE



Drill Hole: TH-5 (SAZDA)
API Density
1000 cps/inch
1% Std Dev
Zero
190 m
200 m
GOT CALIPER TO HERE
4" Base line
[redacted]

GEOSCIENCE ASSOCIATES USGS

HOLE NUMBER: TH-5 (SAZDA)

DATE: 19th March, 1989.

LOCATION

STATE/COUNTY	Sind Pakistan
REGION	DHAKLA, Thar Parkav.
PROJECT	SA2 DA (Ground Water)
PROSPECT	
SEC. TWP. RNG.	

TYPE	GAM			
LOGGED DEPTH				
RANGE (f.s.)				
%STD DEV				
PAPER SPEED "/ft				
LOG SPEED ft/min				
BKGND. COUNT				
PROBE NO.				
SIZE (dia.) in				
K-FACTOR x10⁻⁵				
DEAD TIME µsec				
STANDARD (cps)				

DIGITAL DATA

PRINT INTERVAL				
TIMEBASE sec				

DENSITY CALIBRATION

ALUMINUM				
LUCITE				

HOLE DATA

DEPTH DRILLED:	300.86m
DEPTH LOGGED:	200 m
COLLAR ELEV.	
DIA. FROM TO	
DIA. FROM TO	
DIA. FROM TO	
BOREHOLE MEDIUM	H_2O + Mud.
FLUID LEVEL	

CASING DATA

WALL SIZE	
I.D.	
CASED FROM	0 TO 1.5m
CASING TYPE	

SAMPLE DATA

NON-CORED HOLE ■ CORED HOLE □

SAMPLED INTERVAL	SAMPLE TYPE

REMARKS

CLIENT

CLIENT:	U.S.G.S - G.S.P.
GEOLOGIST:	
UNIT OPERATOR	MEHTAB - MUJEEB
UNIT NO.	PL-2. OFFICE

ELECTRIC

TYPE	RESIST	S.P.
LOGGED DEPTH	FT.	FT.
SCALE	ohm/in	mv/in
PAPER SPEED	"/ft	"/ft
LOG SPEED	ft/min	ft/min
FINE ADJ.		

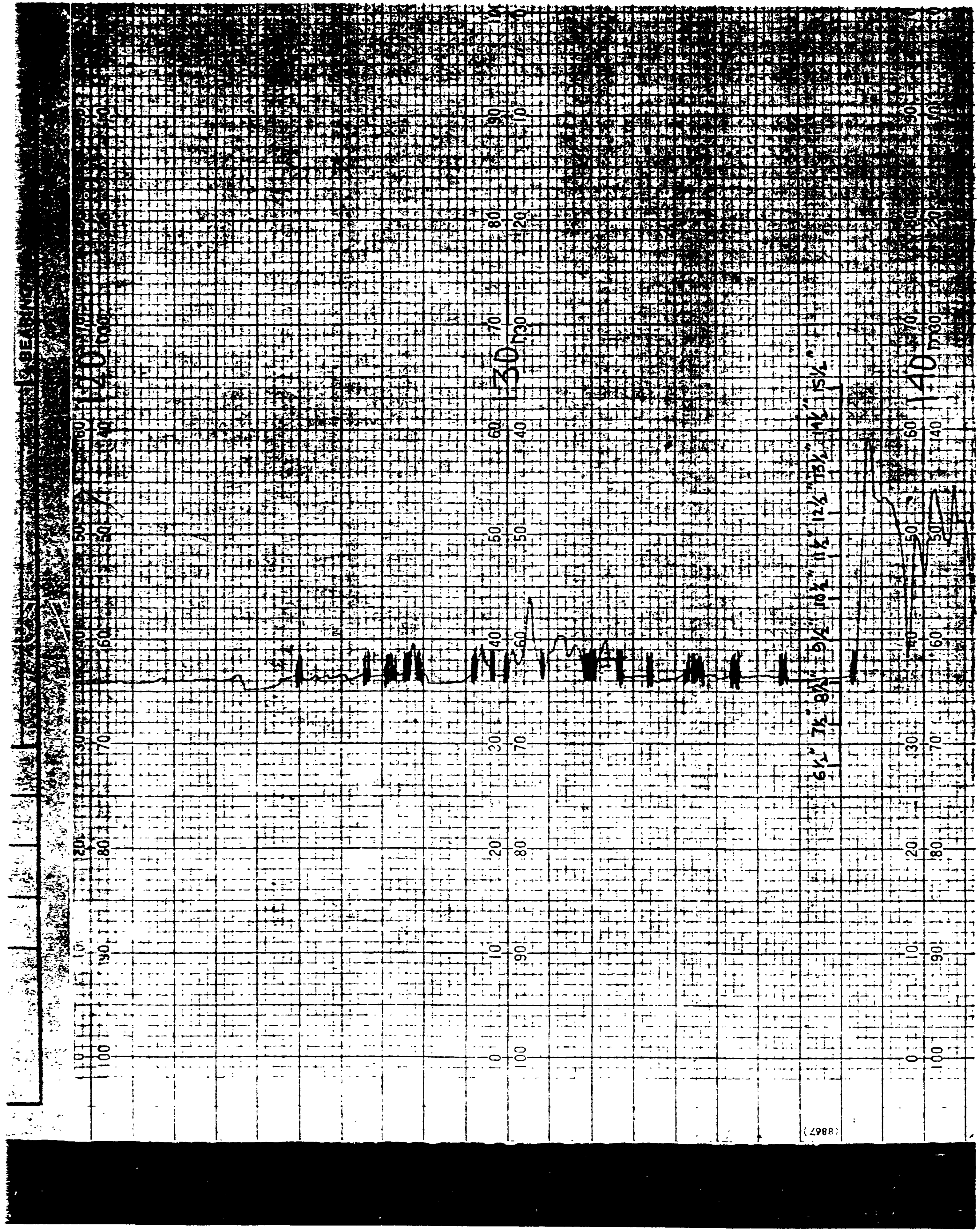
3 ARM CALIPER

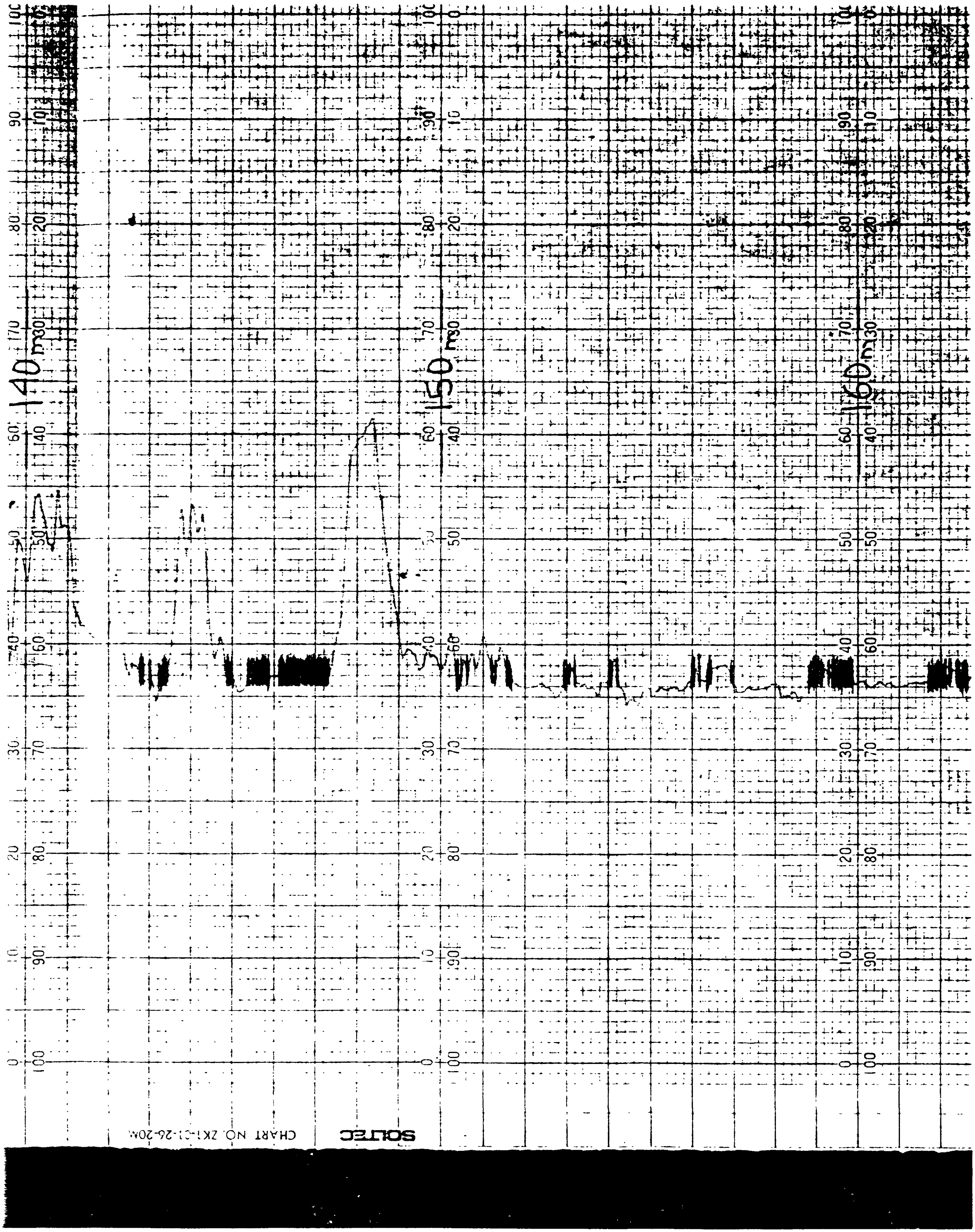
LOGGED DEPTH	200 m	FT.
SCALE	4" Deflection [illegible]	
PAPER SPEED	[illegible]	
LOG SPEED	6-1	
ARM LENGTH	12	IN
MAX DEF.	24	IN

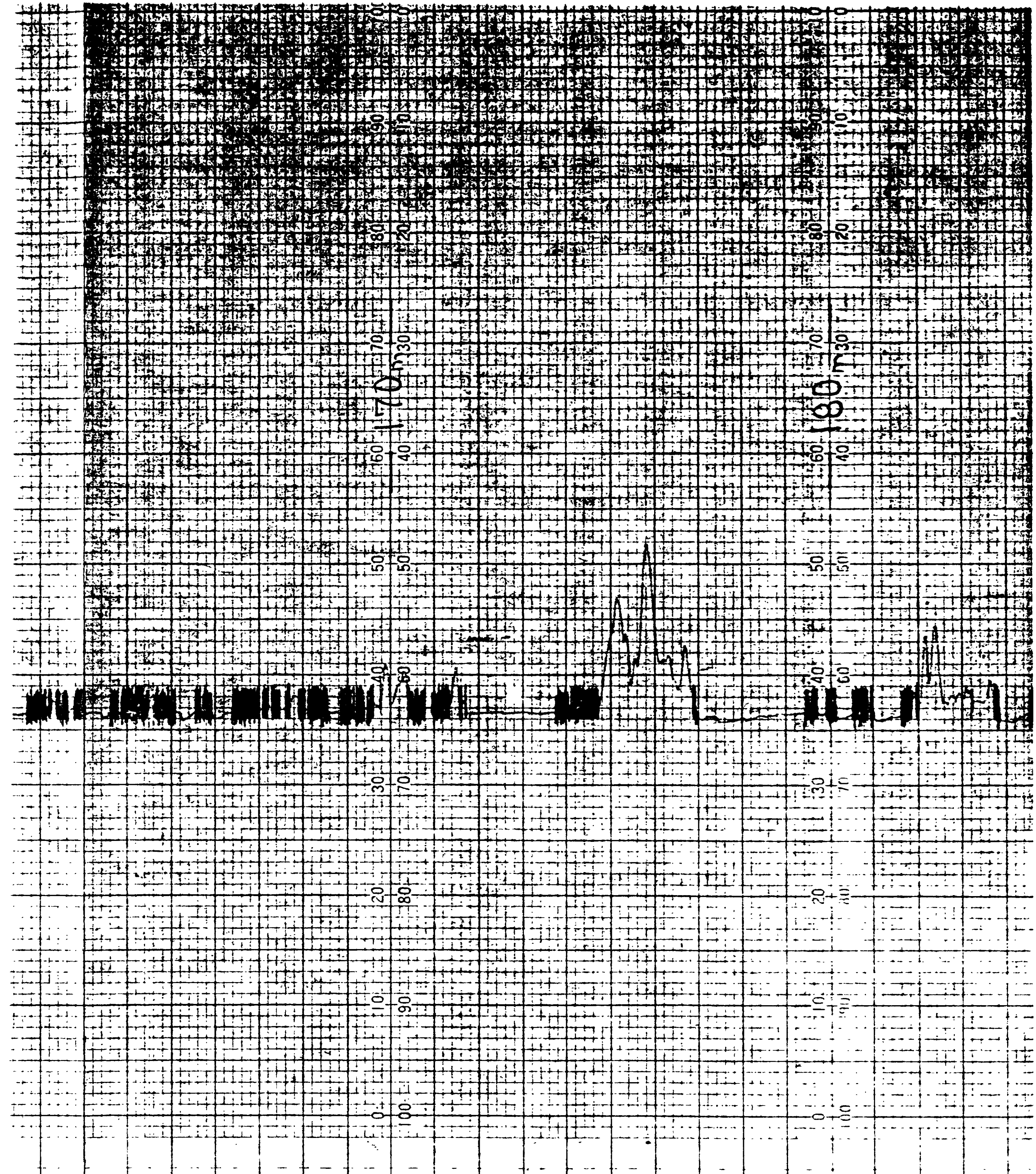
VERTICAL DEV.

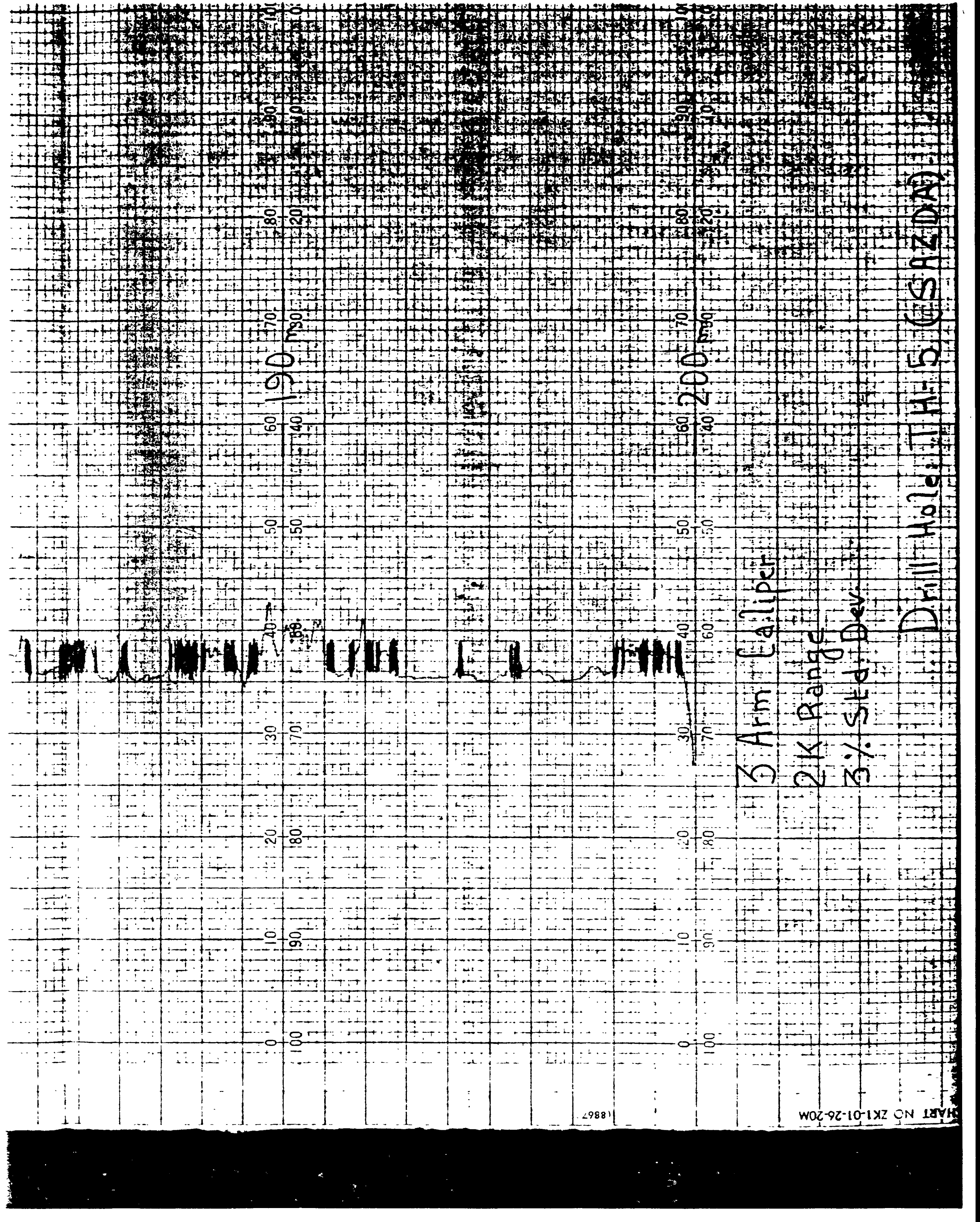
DEPTH				
INCLIN.				
BEARING				

120 m




140 m
150 m
160 m


170 m
180 m



Drill Hole TH-5 (GSAZDA)
3 Arm Caliper
2K Range
3% Std. Dev.
190
200
CHART NO ZK1-01-26-20M

GEOSCIENCE ASSOCIATES

HOLE NUMBER: Chhachro – T.H.6 – SALDA.

DATE: July 2nd ~~June~~, 1989

LOCATION

STATE/COUNTY: Pakistan
REGION: Chhachro, Sindh
PROJECT
PROSPECT
SEC. TWP. RNG.

TYPE	GAM		Neutron	
LOGGED DEPTH	298 m		300 m	
RANGE (f.s.)	100		500	
%STD DEV	3%		1%	
PAPER SPEED	1–1		1–1	
LOG SPEED	6–1		6–1	
BKGND. COUNT				
PROBE NO.	GN-1		GN-1	
SIZE (dia.)	1 3/8"		1 3/8"	
K-FACTOR				
DEAD TIME	2		2	
STANDARD				

DIGITAL DATA

PRINT INTERVAL				
TIMEBASE				

DENSITY CALIBRATION

ALUMINUM				
LUCITE				

HOLE DATA

DEPTH DRILLED: 300.85 m
DEPTH LOGGED: 300 m
COLLAR ELEV.
DIA. 12" FROM TO
DIA. FROM TO
DIA. FROM TO
BOREHOLE MEDIUM: Mud + H_2O
FLUID LEVEL

CASING DATA

WALL SIZE
I.D.
CASED FROM 0 TO 1.2 m
CASING TYPE

SAMPLE DATA

NON-CORED HOLE ☒ CORED HOLE ☐
SAMPLED INTERVAL | SAMPLE TYPE

REMARKS

Open Hole.

CLIENT

CLIENT
GEOLOGIST:
UNIT OPERATOR: MUJEEB
UNIT NO. PL-2 OFFICE G.S.P.

ELECTRIC

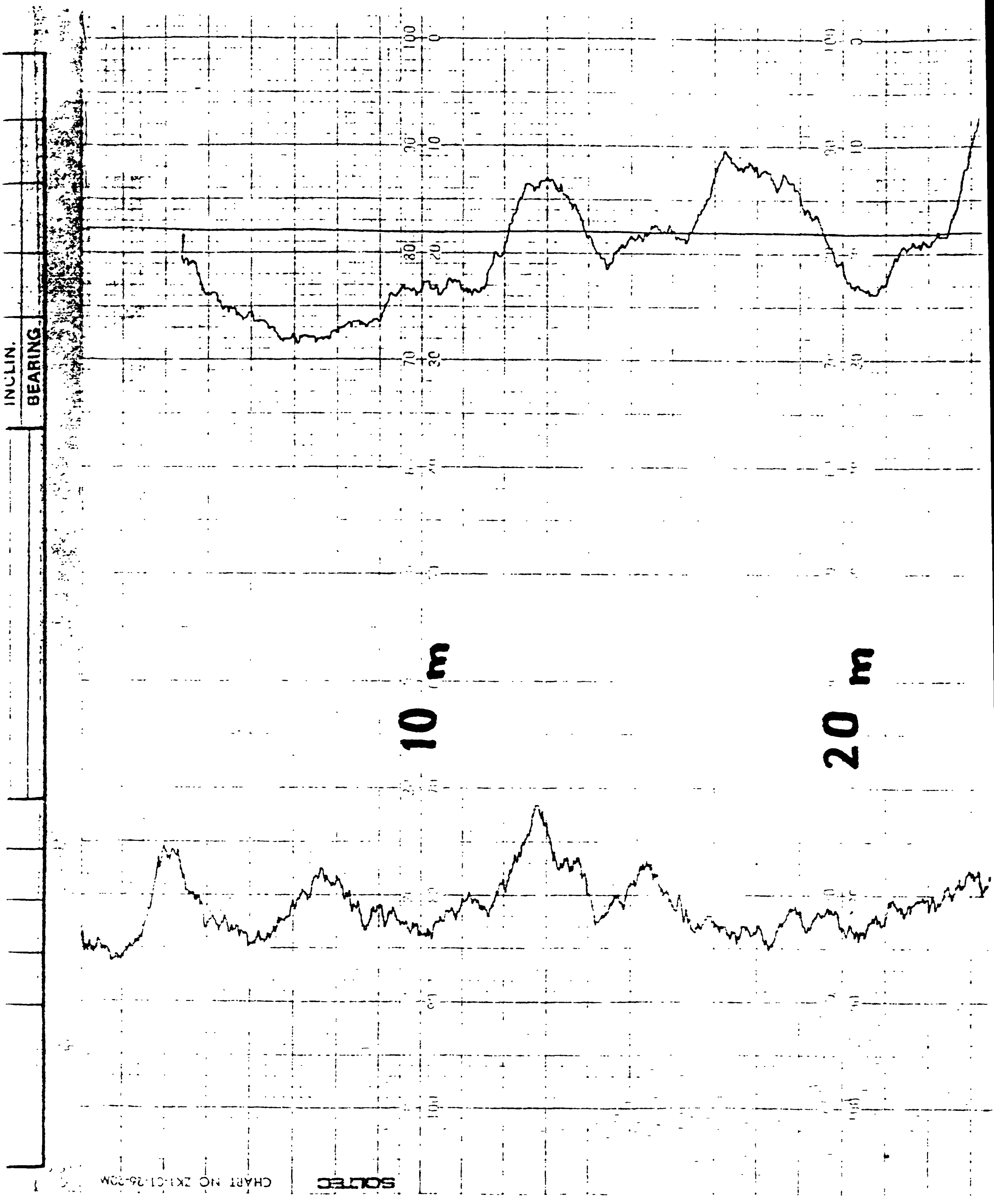
TYPE	RESIST	S.P.
LOGGED DEPTH	300 m	FT.
SCALE	1000 ohms/in	mv/in
PAPER SPEED	1–1 in/m	
LOG SPEED	6–1 m/min	/min
FINE ADJ.	600 Blds.	

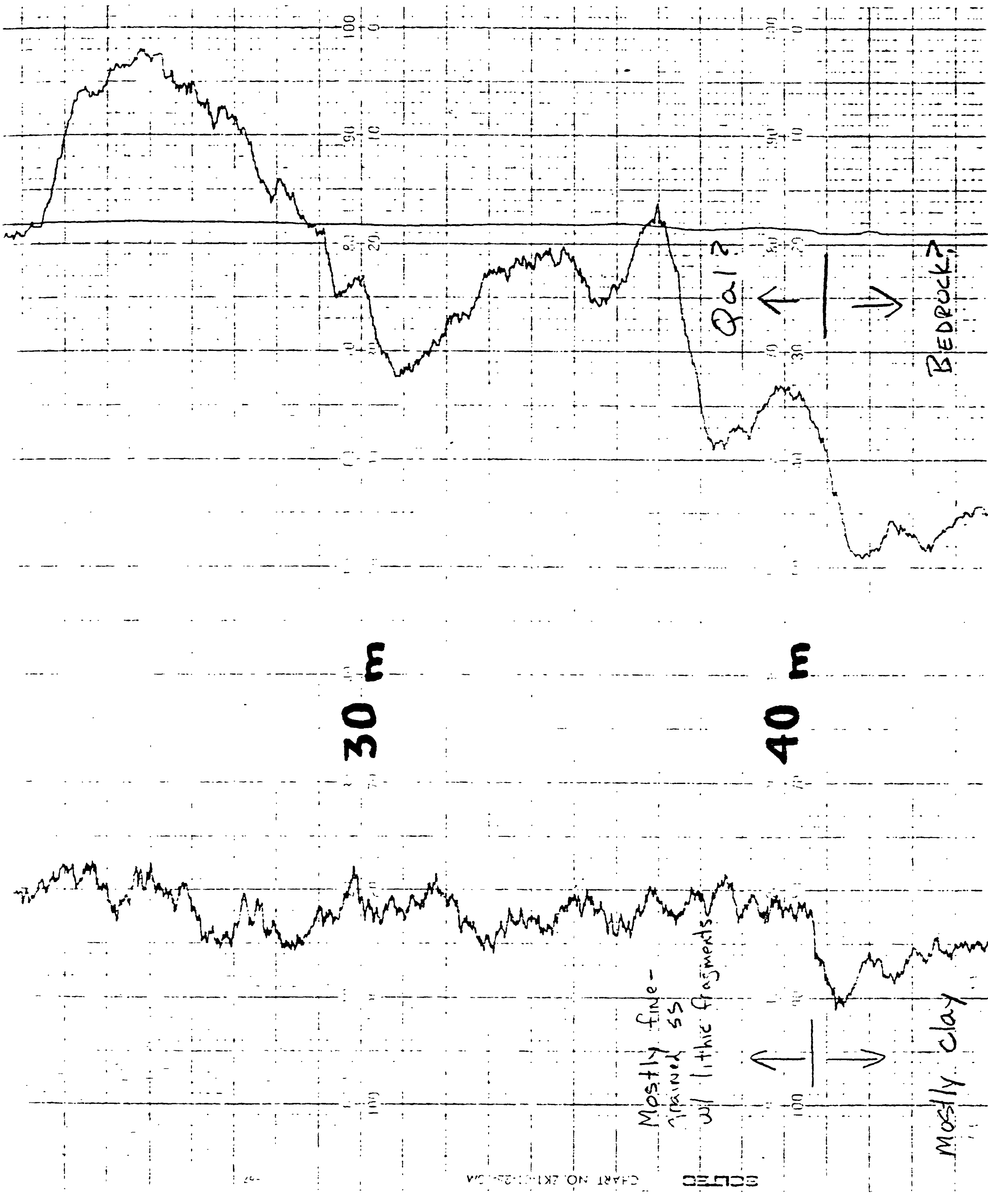
CALIPER

LOGGED DEPTH FT.
SCALE
PAPER SPEED
LOG SPEED
ARM LENGTH IN
MAX DEF. IN

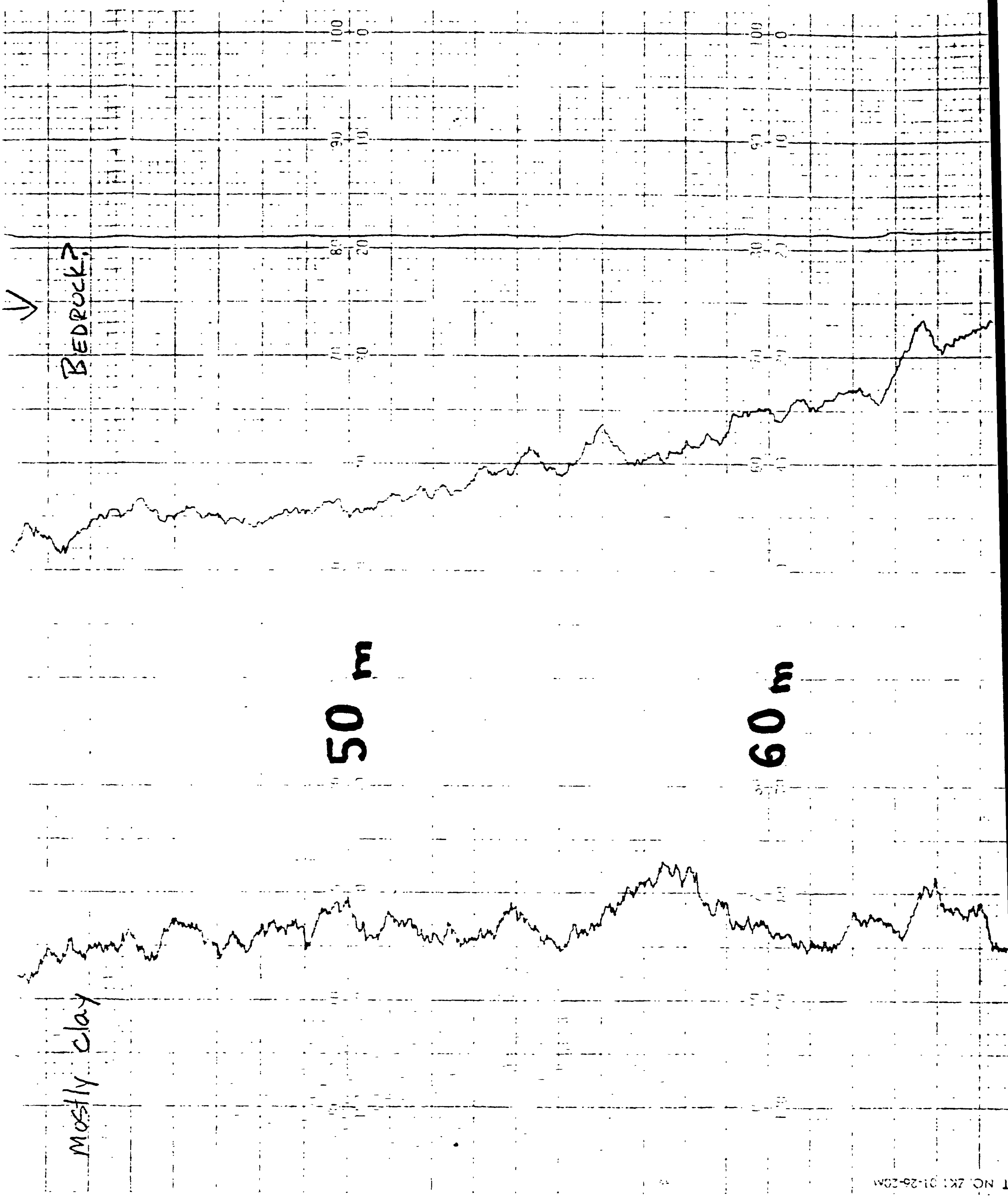
VERTICAL DEV.

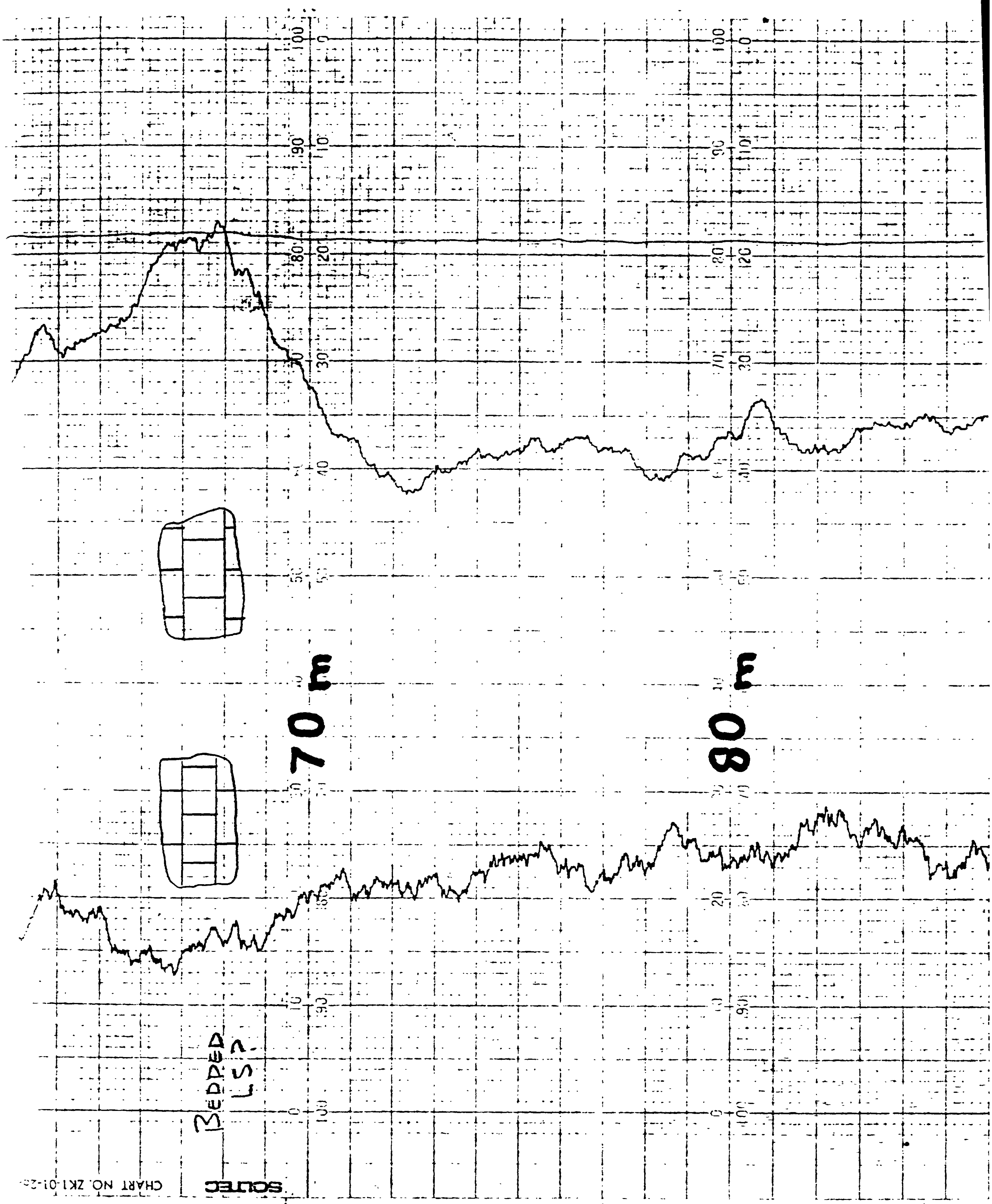
DEPTH				
INCLIN.				
BEARING				

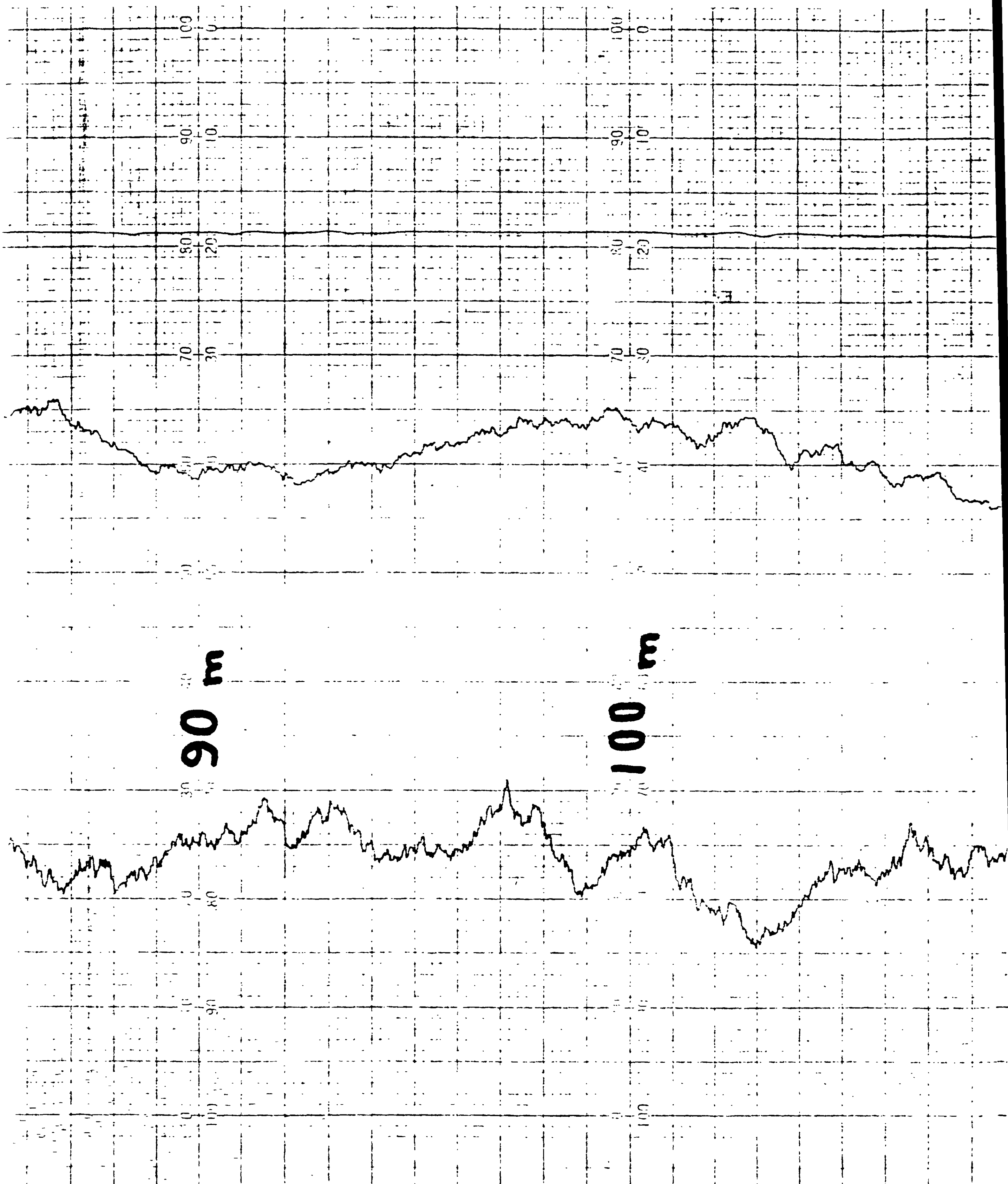

INCLIN.
BEARING.
10 m
20 m

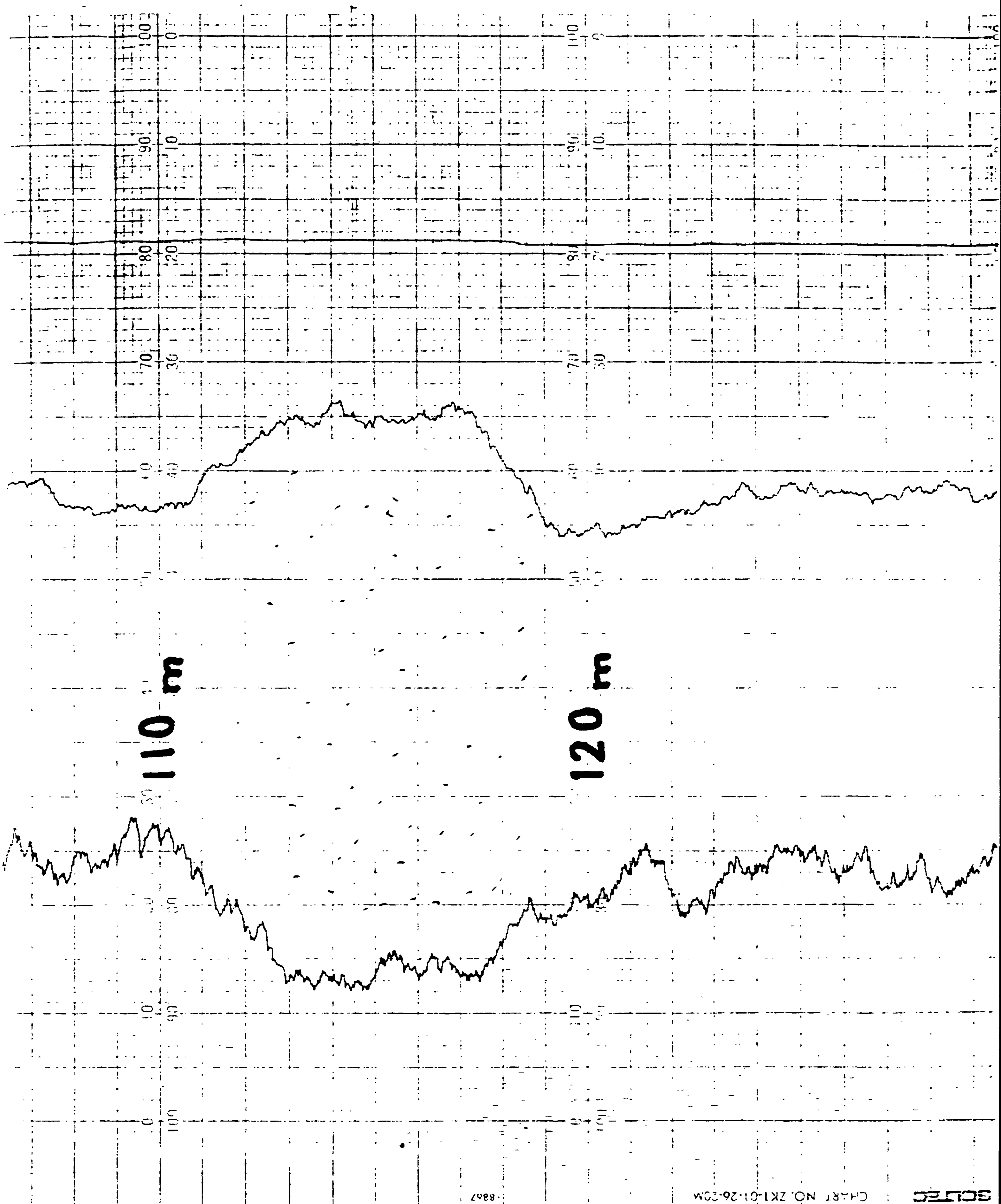


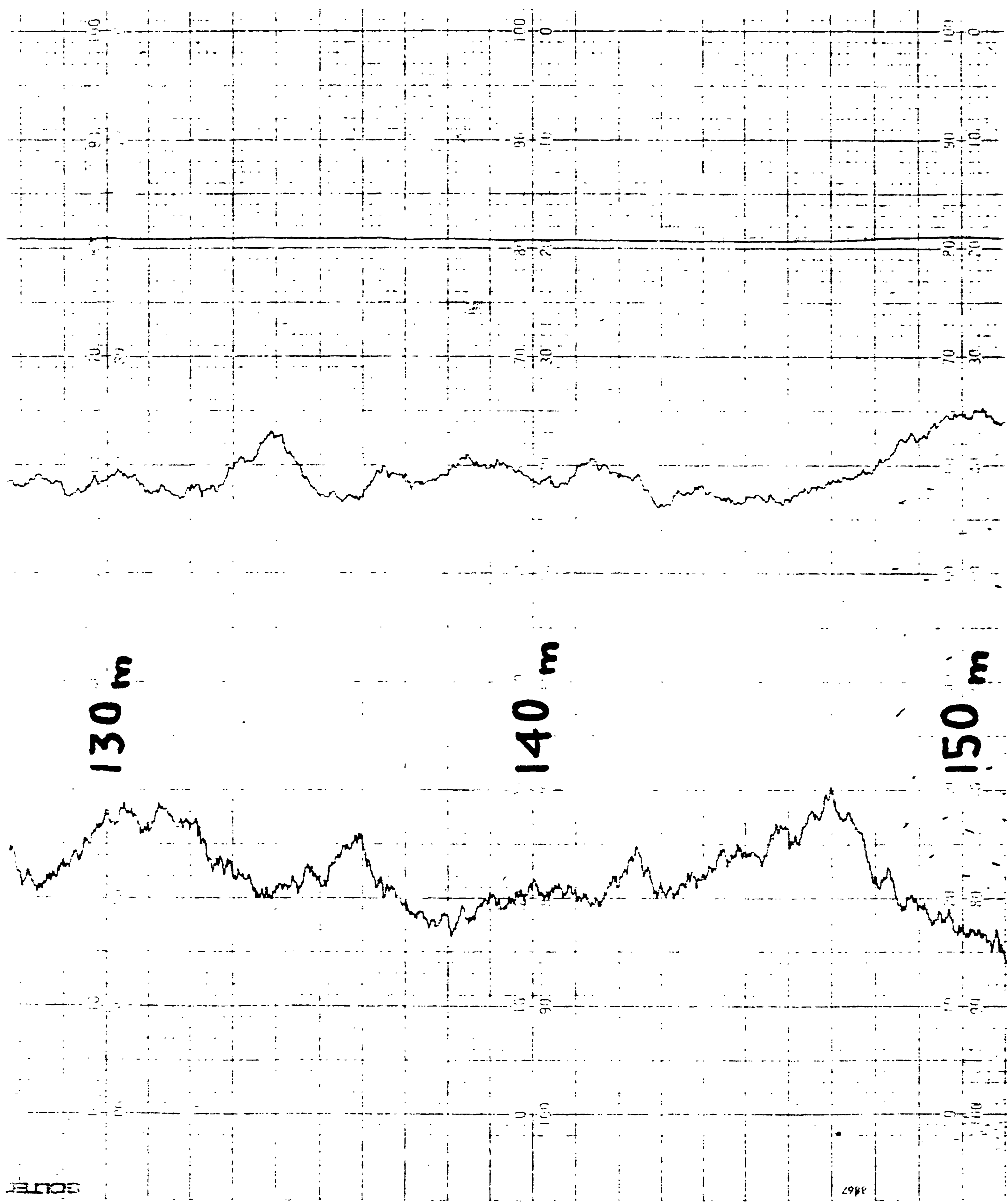
Qal?
Bedrock?
30 m
40 m
Mostly fine-grained SS w/ lithic fragments
Mostly clay

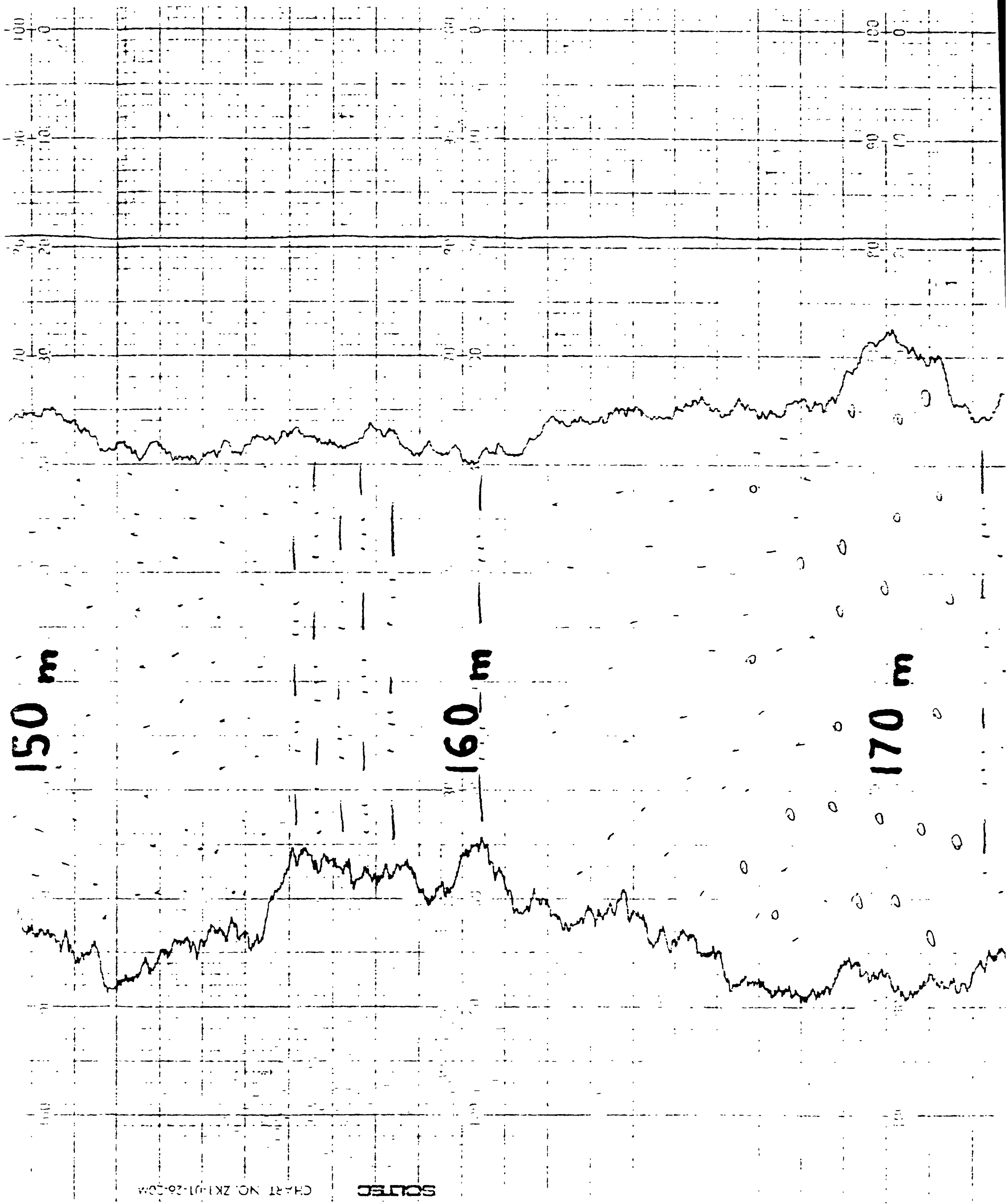

Bedrock?
50 m
60 m
Mostly clay

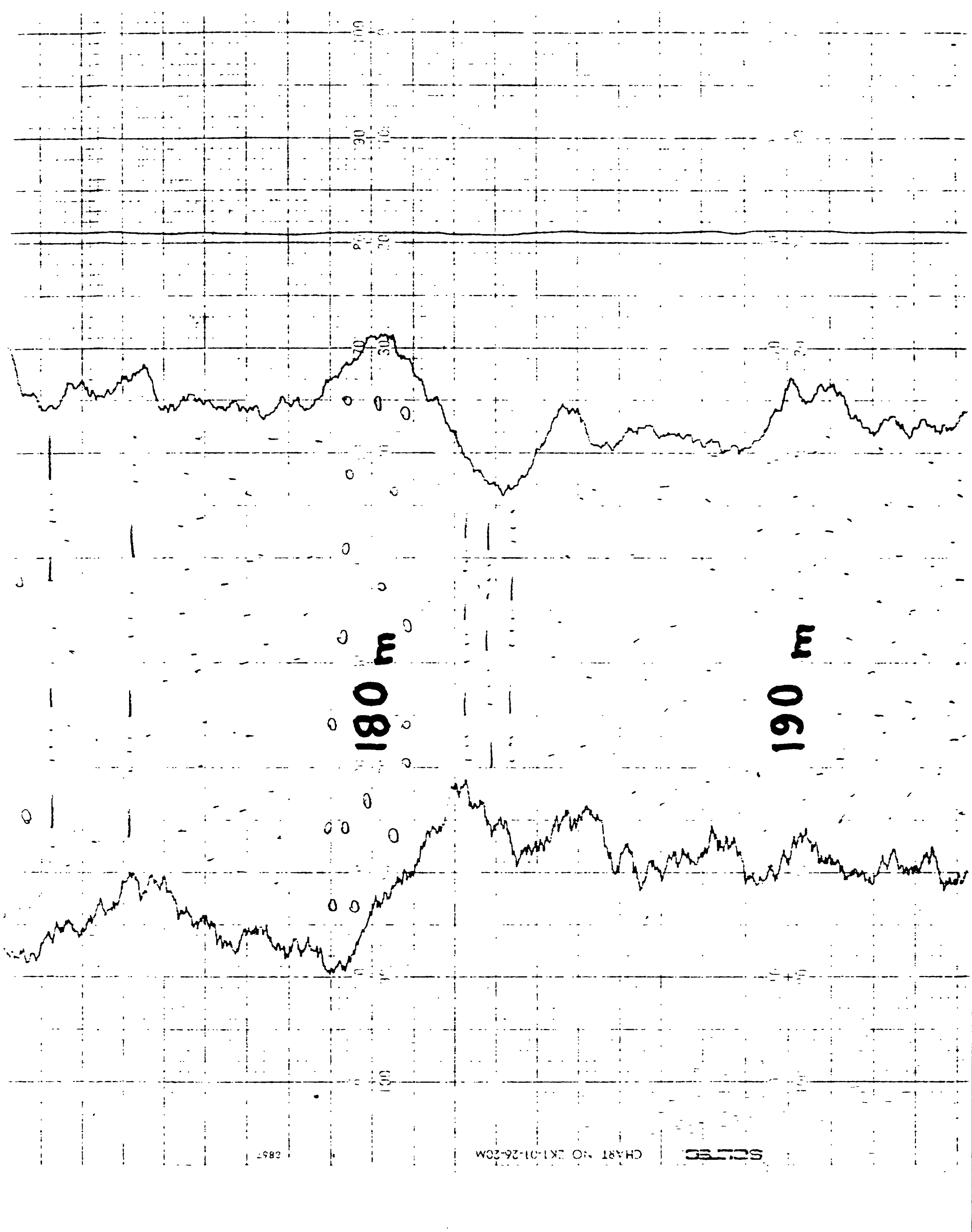

70 m
80 m
BEDDED LS?
SOLTEC
CHART NO. ZK1-01-2

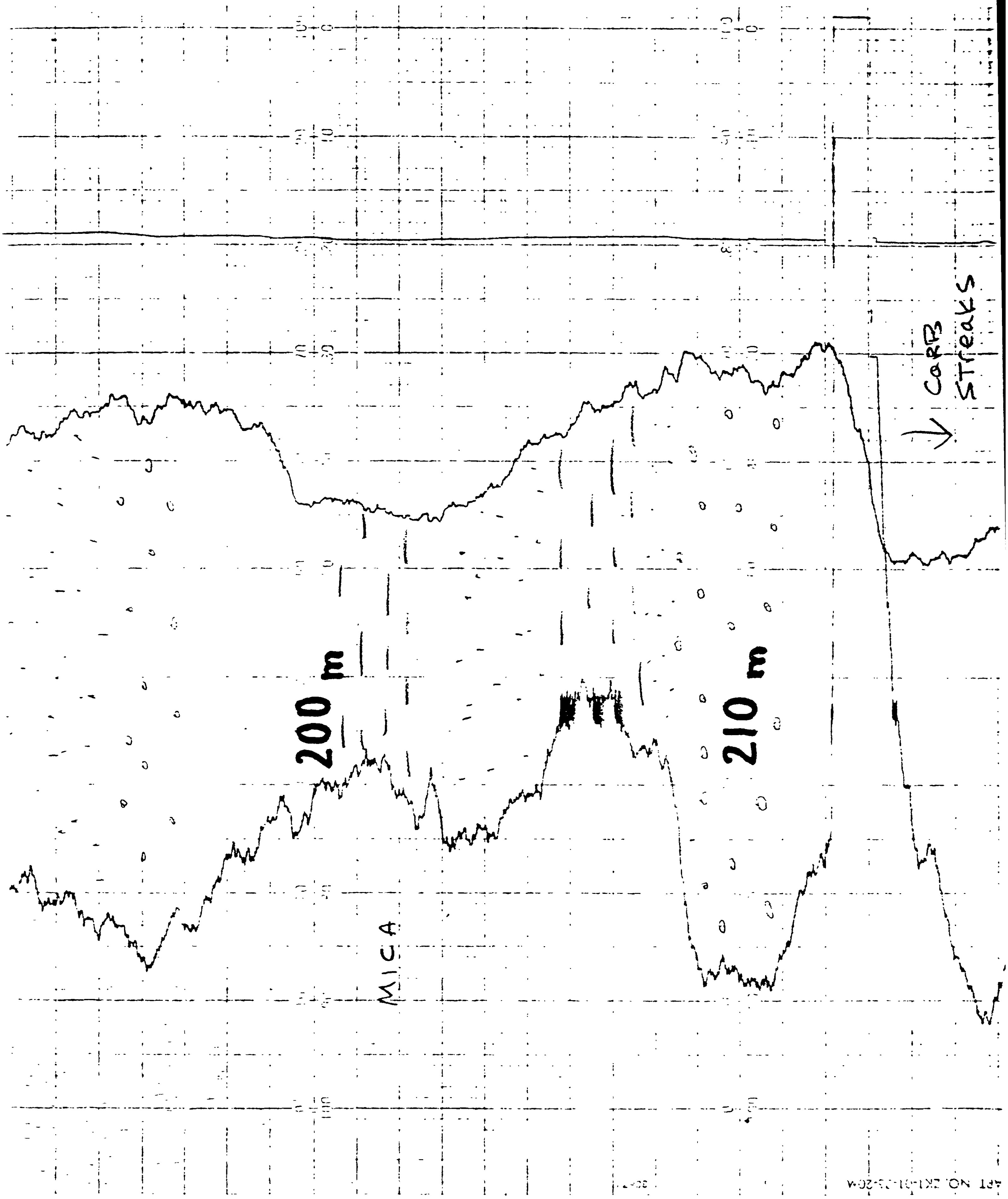

90 m
100 m
CHART NO. ZK1-01-26-20M
SOLTEC


110 m
120 m

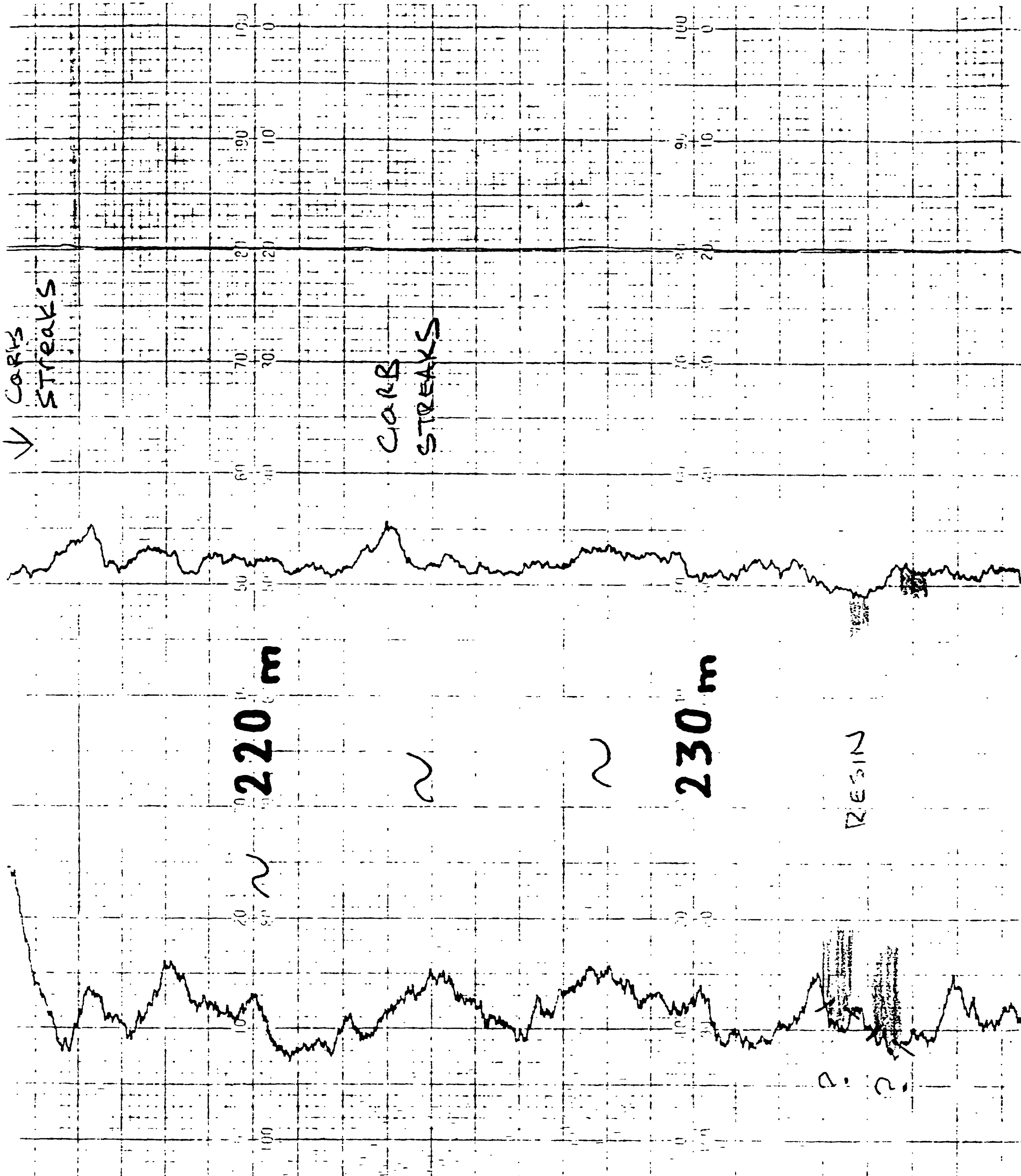

130 m
140 m
150 m

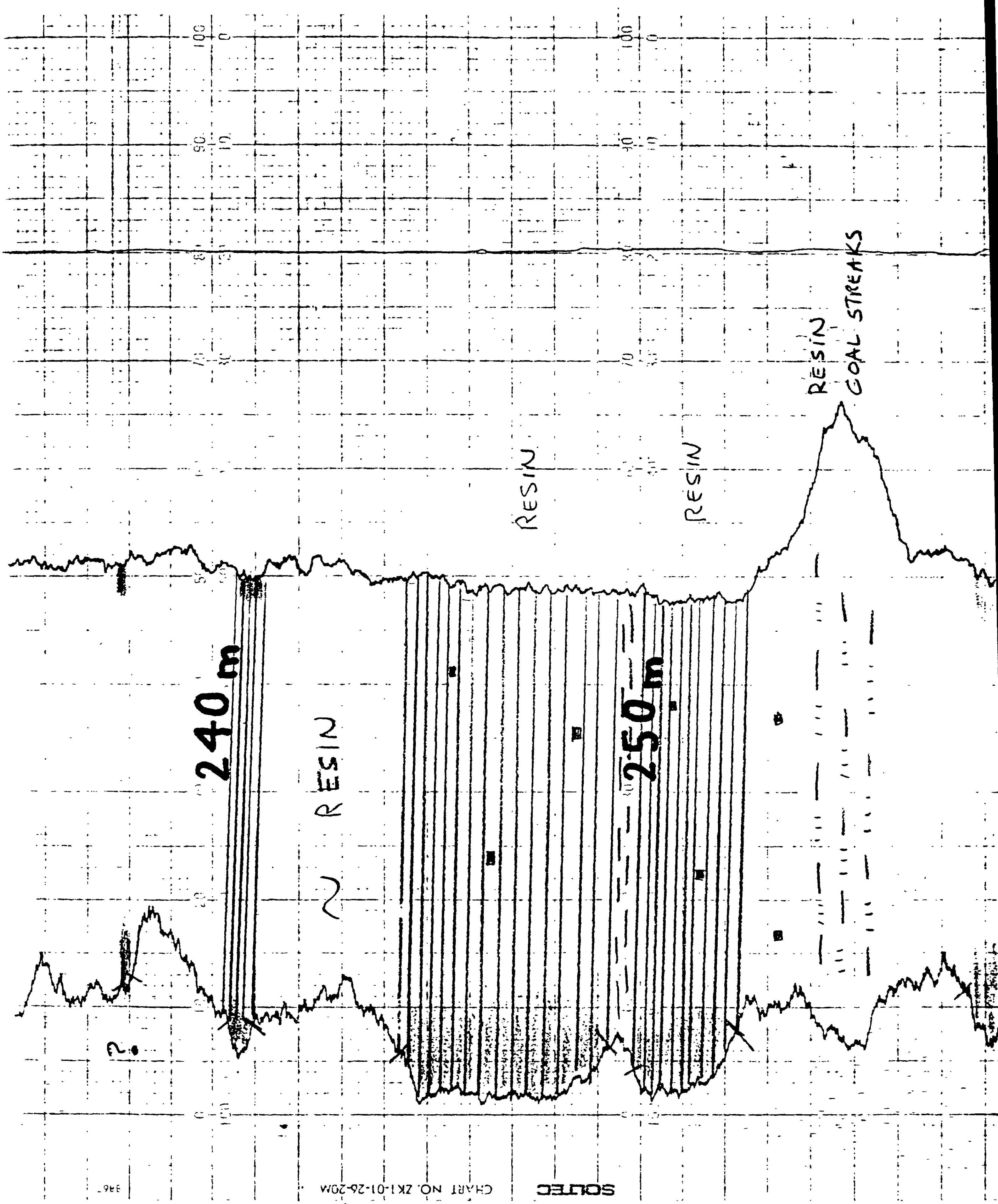

150 m
160 m
170 m

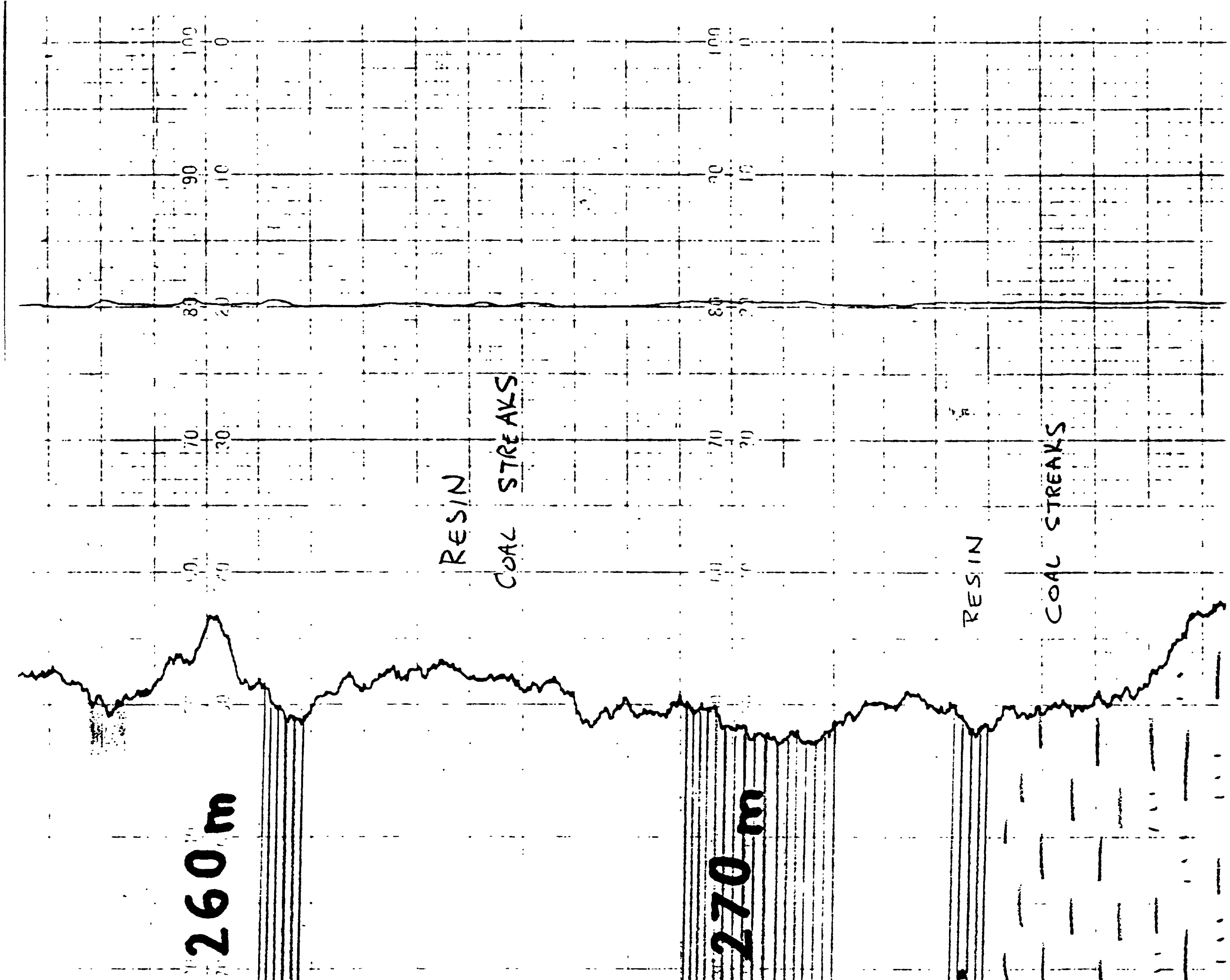

180 m
190 m

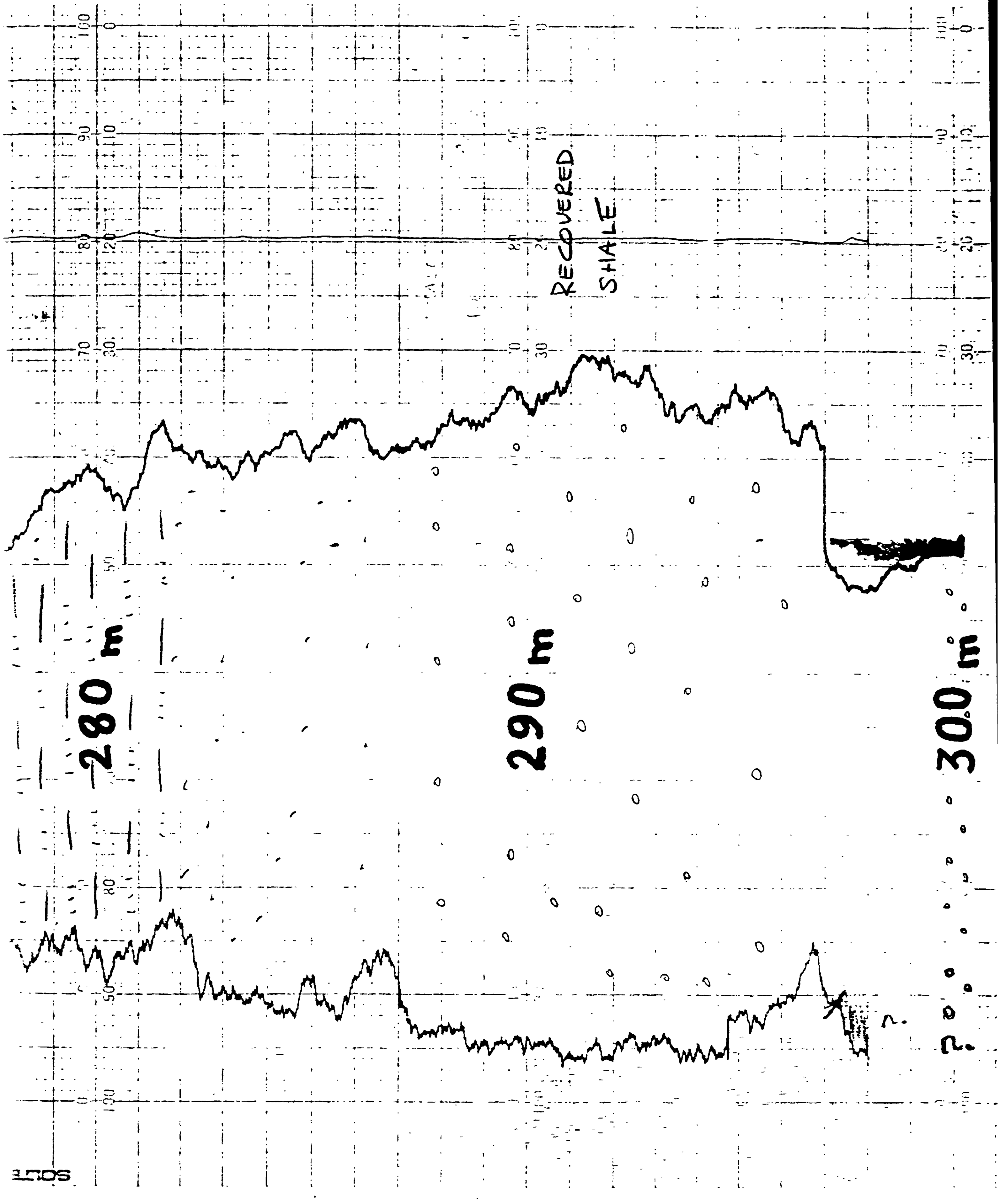


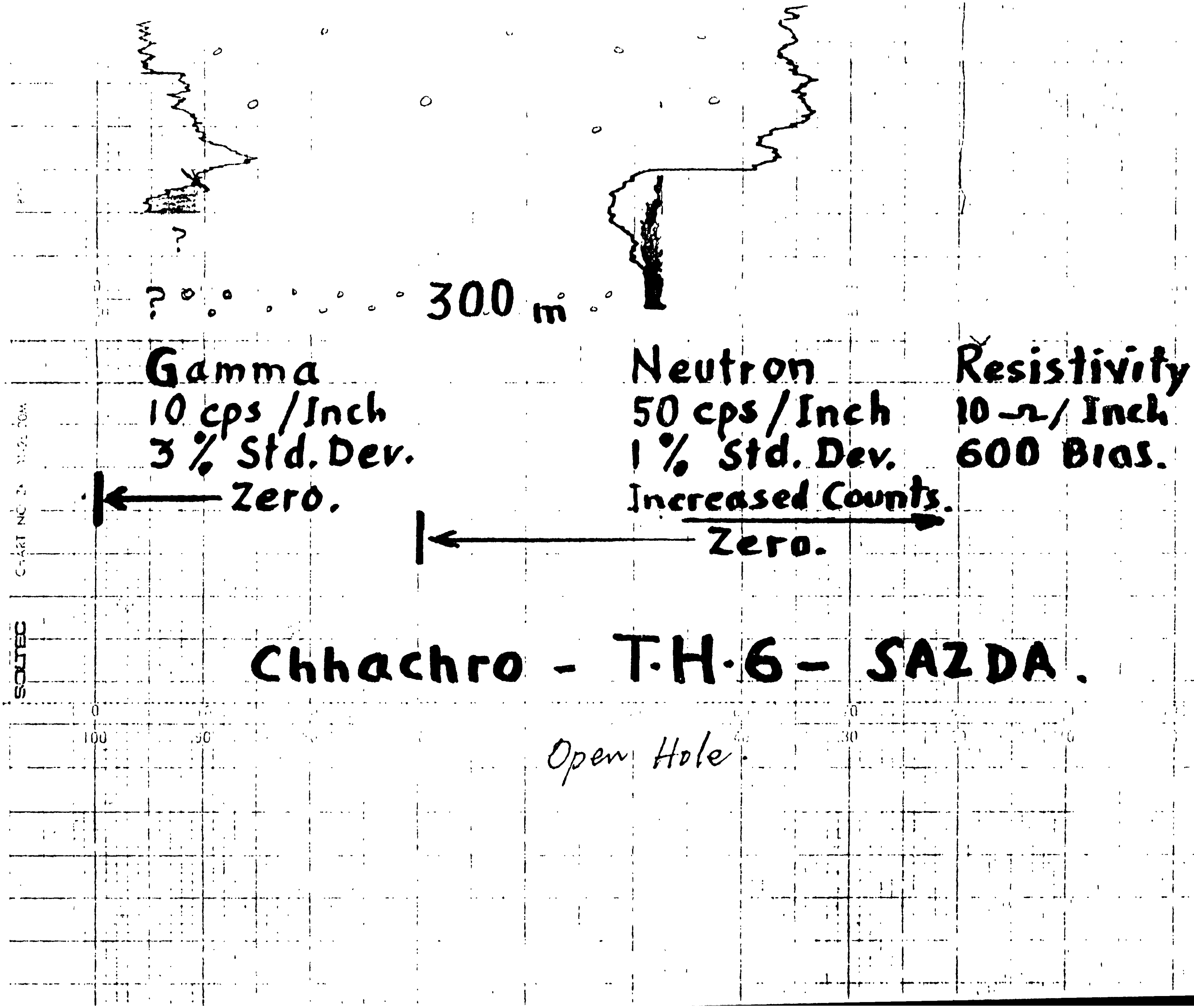
200 m
210 m
MICA
CaRB Streaks


CARB STREAKS
CARB STREAKS
220 m
230 m
RESIN
SOLTEC
CHART NO. 2


240 m
RESIN
RESIN
RESIN
250 m
RESIN
COAL STREAKS
SOLTEC
CHART NO. ZK1-01-26-20M


260 m
270 m
RESIN
COAL STREAKS
RESIN
COAL STREAKS


RECOVERED SHALE
280 m
290 m
300 m


300 m
Gamma
10 cps /Inch
3 % Std. Dev.
Zero.
Neutron
50 cps / Inch
1 % Std. Dev.
Increased Counts.
Zero.
Resistivity
10 Ω / Inch
600 Bias.
Chhachro - T.H.6 - SAZDA.
Open Hole.
SOLTEC

GEOSCIENCE ASSOCIATES

HOLE NUMBER: Chhachro - T.H.6 - SAZDA.

DATE: July 2nd, ~~June~~ 1989.

LOCATION

STATE/COUNTY Pakistan.

REGION Chhachro.

PROJECT

PROSPECT

SEC. TWP. RNG.

TYPE	GAM	API Density		
LOGGED DEPTH		300 m		
RANGE (f.s.)		20K		
%STD DEV		1%		
PAPER SPEED		1-1		
LOG SPEED		6-1		
BKGND. COUNT				
PROBE NO.		CD-1		
SIZE (dia.)		1 3/8"		
K-FACTOR				
DEAD TIME		2		
STANDARD				

DIGITAL DATA

PRINT INTERVAL				
TIMEBASE sec				

DENSITY CALIBRATION

ALUMINUM				
LUCITE				

HOLE DATA

DEPTH DRILLED: 300.85 m

DEPTH LOGGED: 300 m

COLLAR ELEV.

DIA. 12" FROM 0 TO 300.85 m

DIA. FROM TO

DIA. FROM TO

BOREHOLE MEDIUM Mud + H_2O

FLUID LEVEL

CASING DATA

WALL SIZE

I.D.

CASED FROM 0 TO 1.2 m

CASING TYPE

SAMPLE DATA

NON-CORED HOLE (X) CORED HOLE ( )

SAMPLED INTERVAL | SAMPLE TYPE

REMARKS

Open Hole.

CLIENT

CLIENT

GEOLOGIST:

UNIT OPERATOR Mujeeb Ahmad.

UNIT NO. PL-2 OFFICE

ELECTRIC

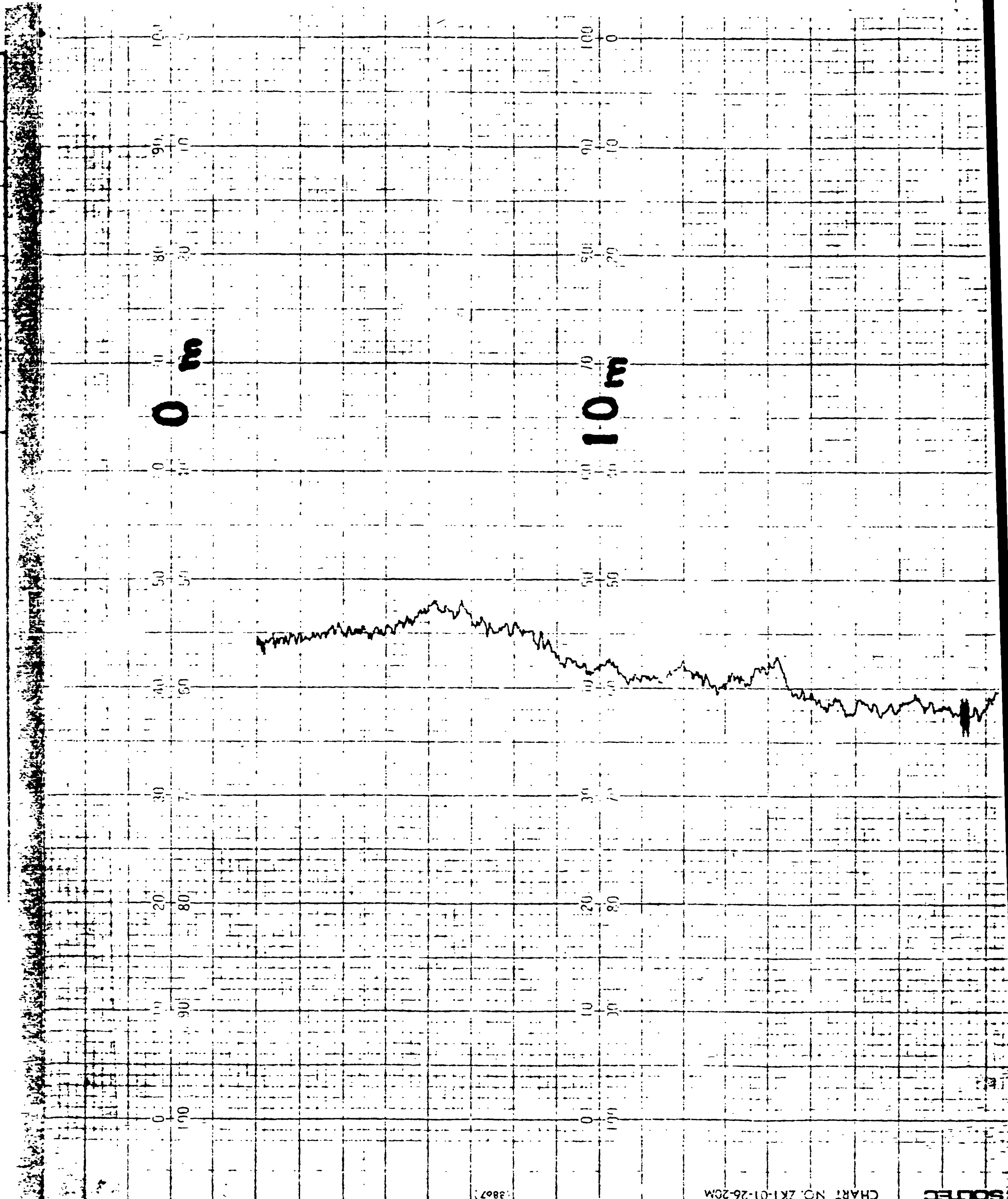
TYPE	RESIST	S.P.
LOGGED DEPTH	FT.	FT.
SCALE		
PAPER SPEED		
LOG SPEED		
FINE ADJ.		

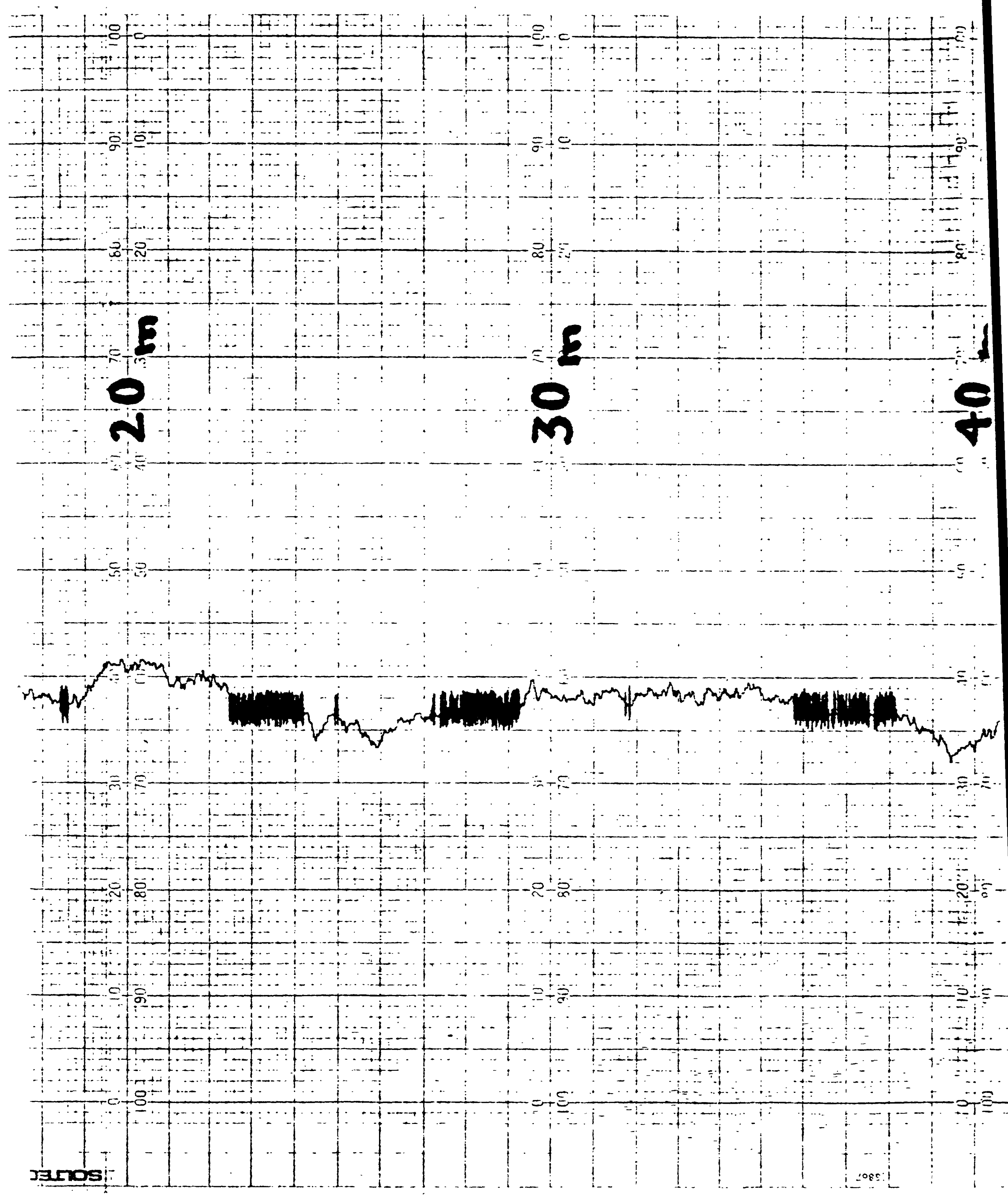
CALIPER

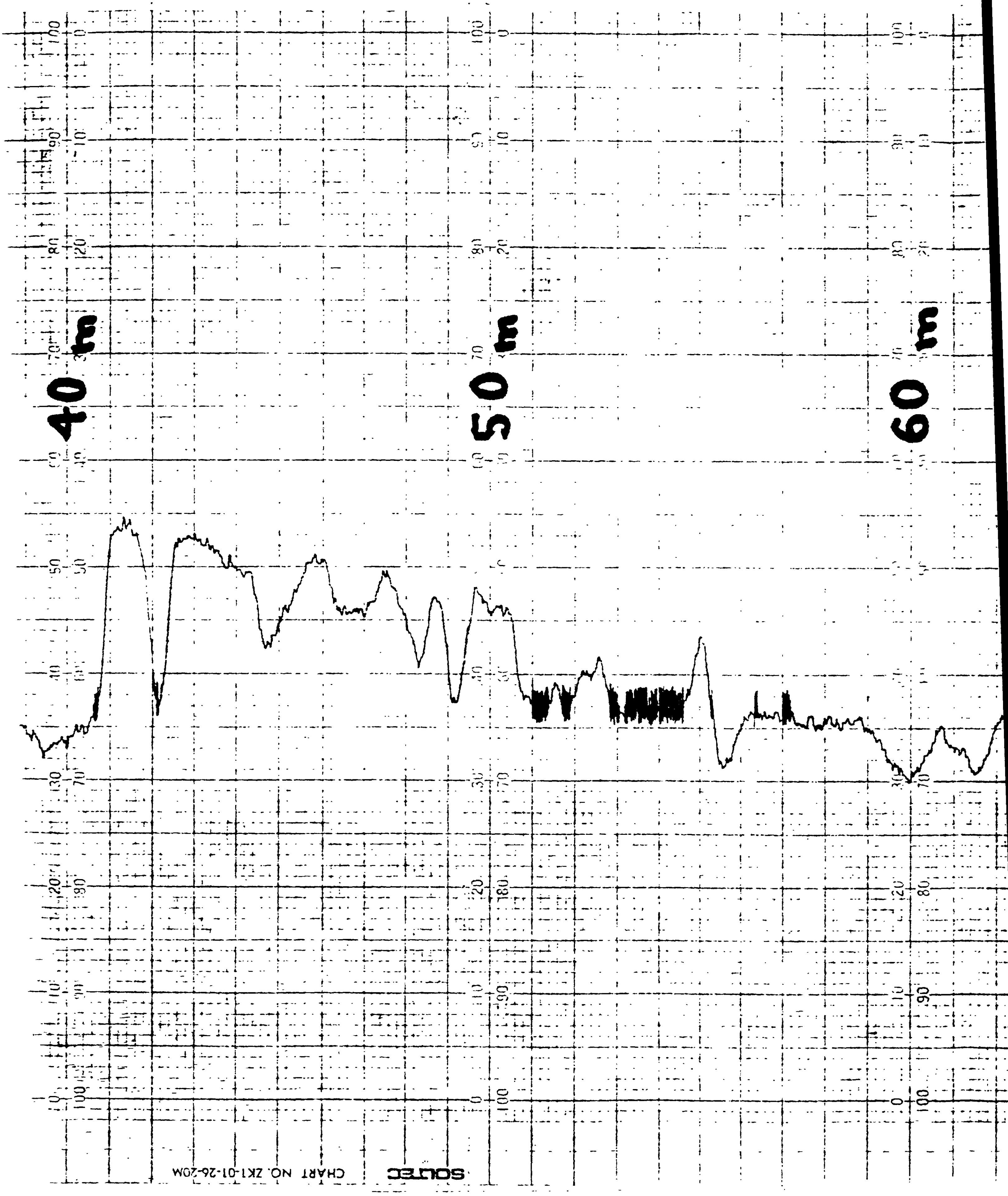
LOGGED DEPTH	FT.
SCALE	
PAPER SPEED	
LOG SPEED	
ARM LENGTH	IN
MAX DEF.	IN

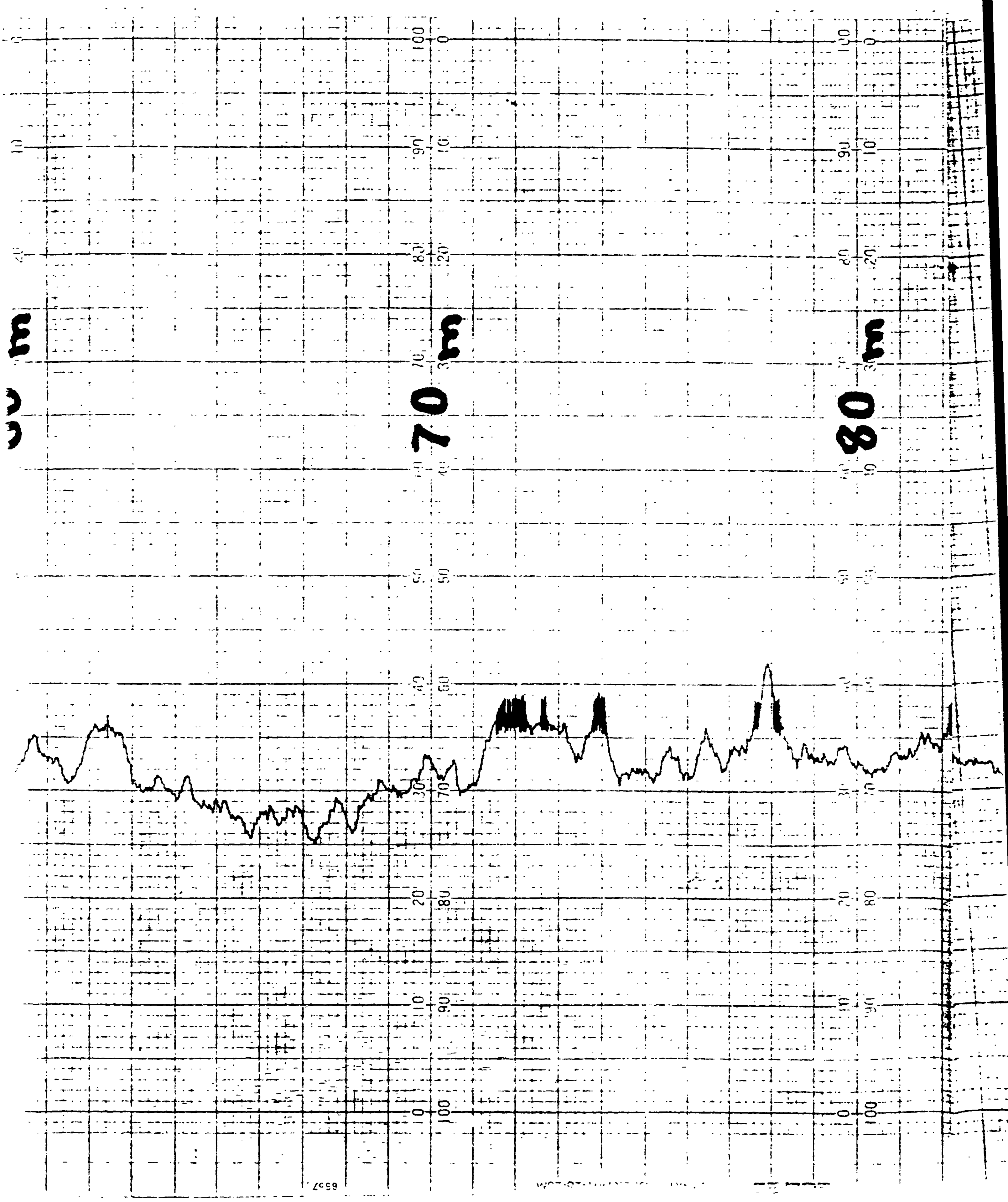
VERTICAL DEV.

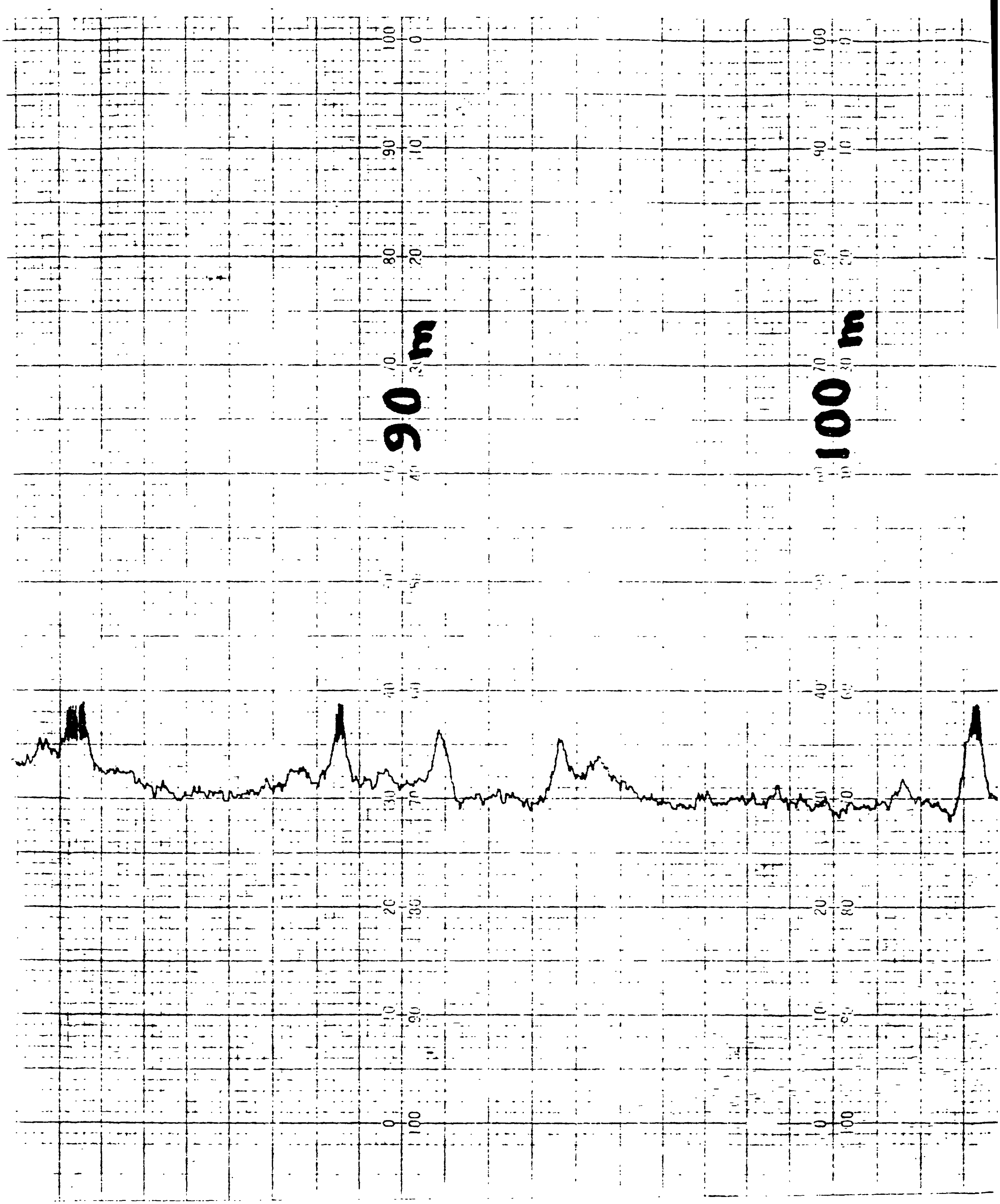
DEPTH				
INCLIN.				
BEARING				


0
10
CHART NO. ZK1-01-26-20M
SOLTEC

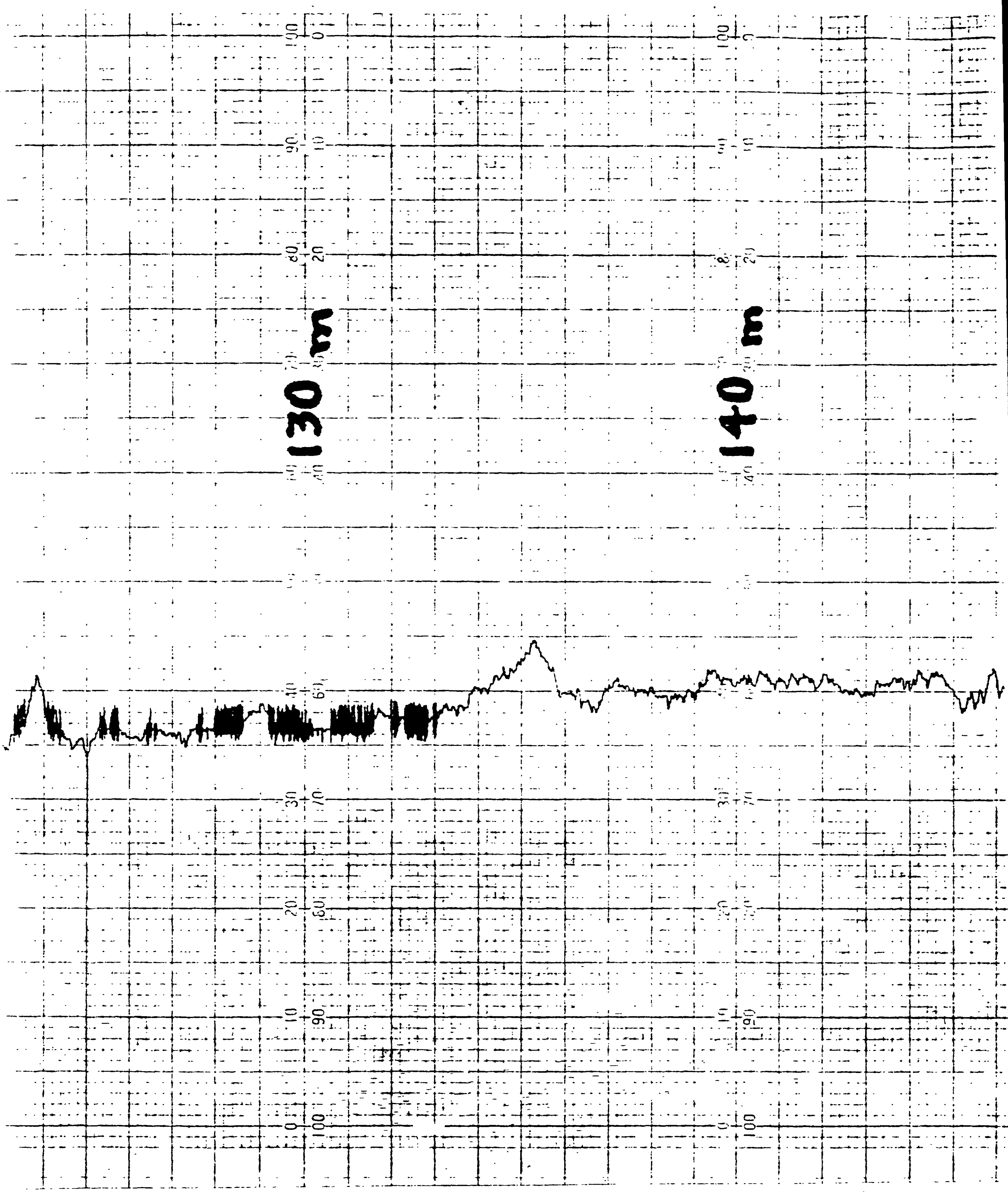

20 m
30 m
40

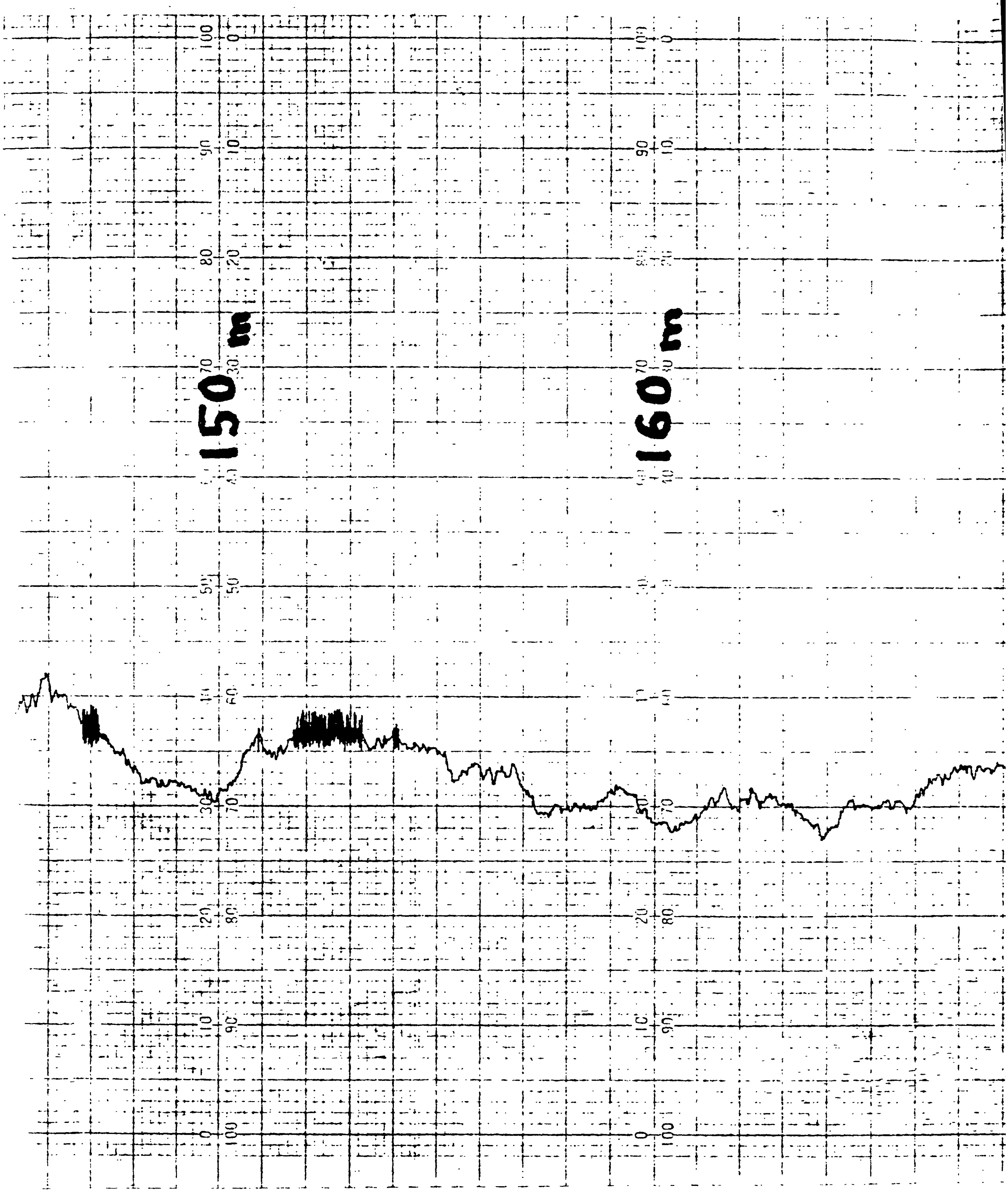

40 m
50 m
60 m
SOLTEC
CHART NO. ZK1-01-26-20M

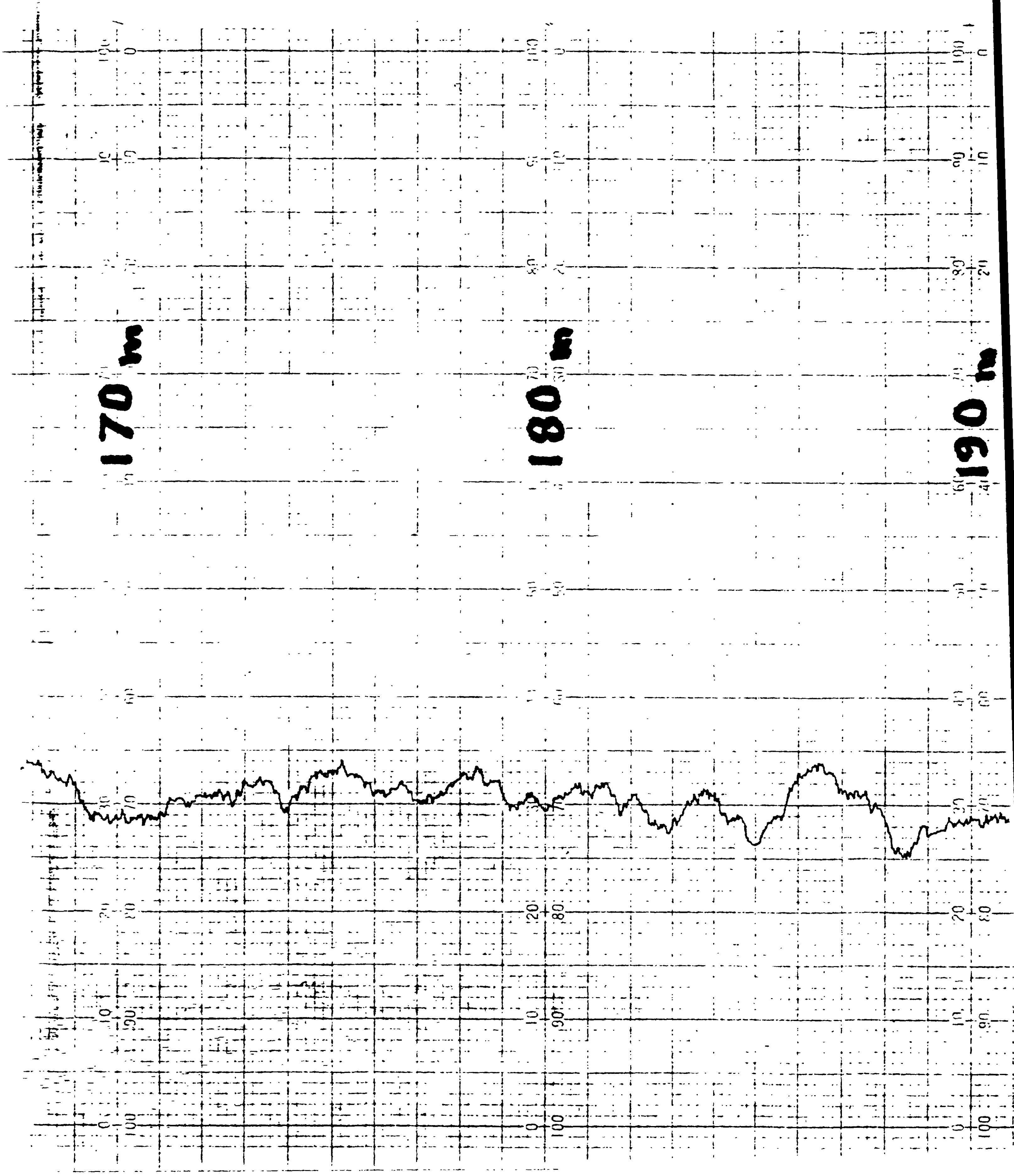


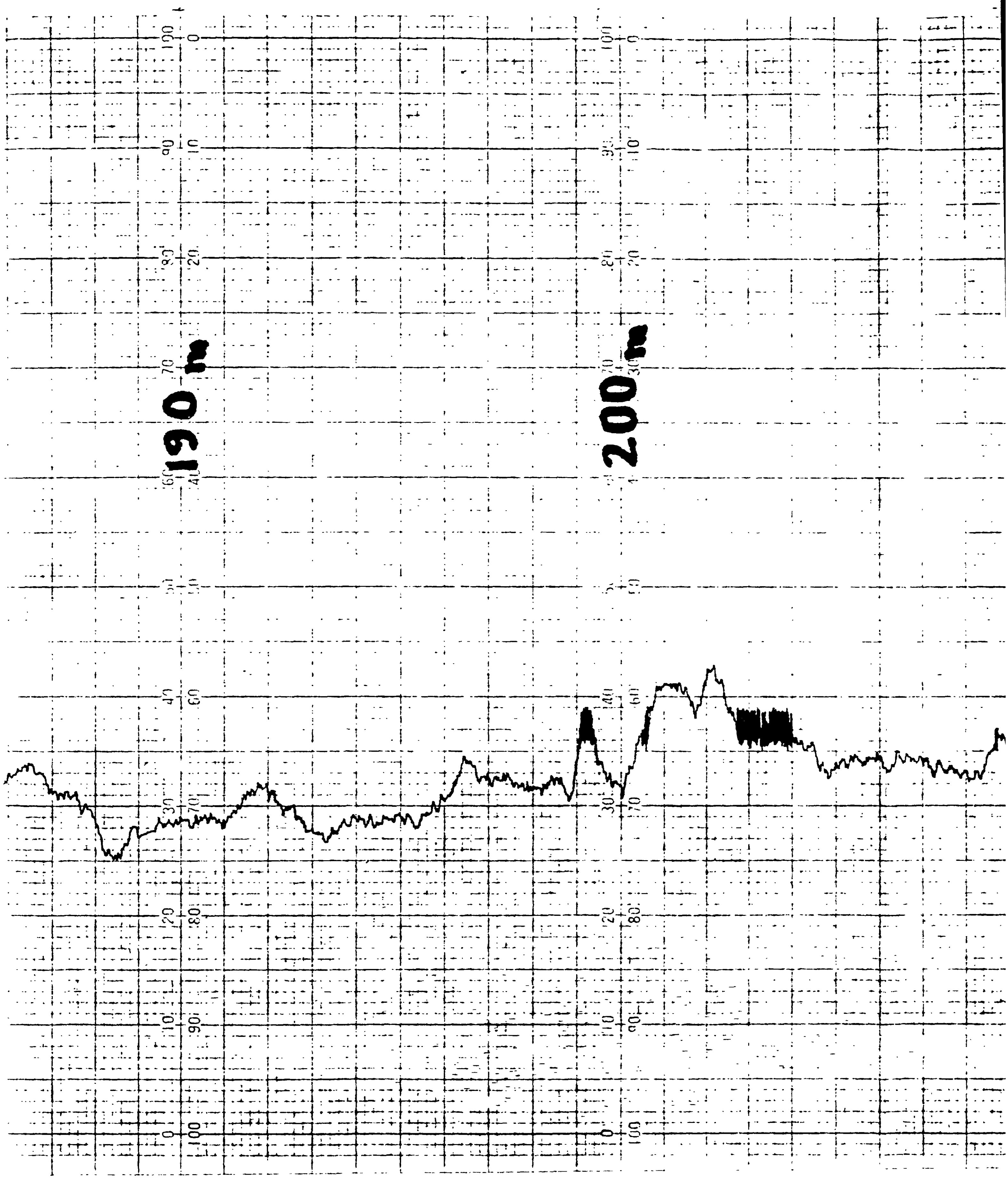

90 m
100 m

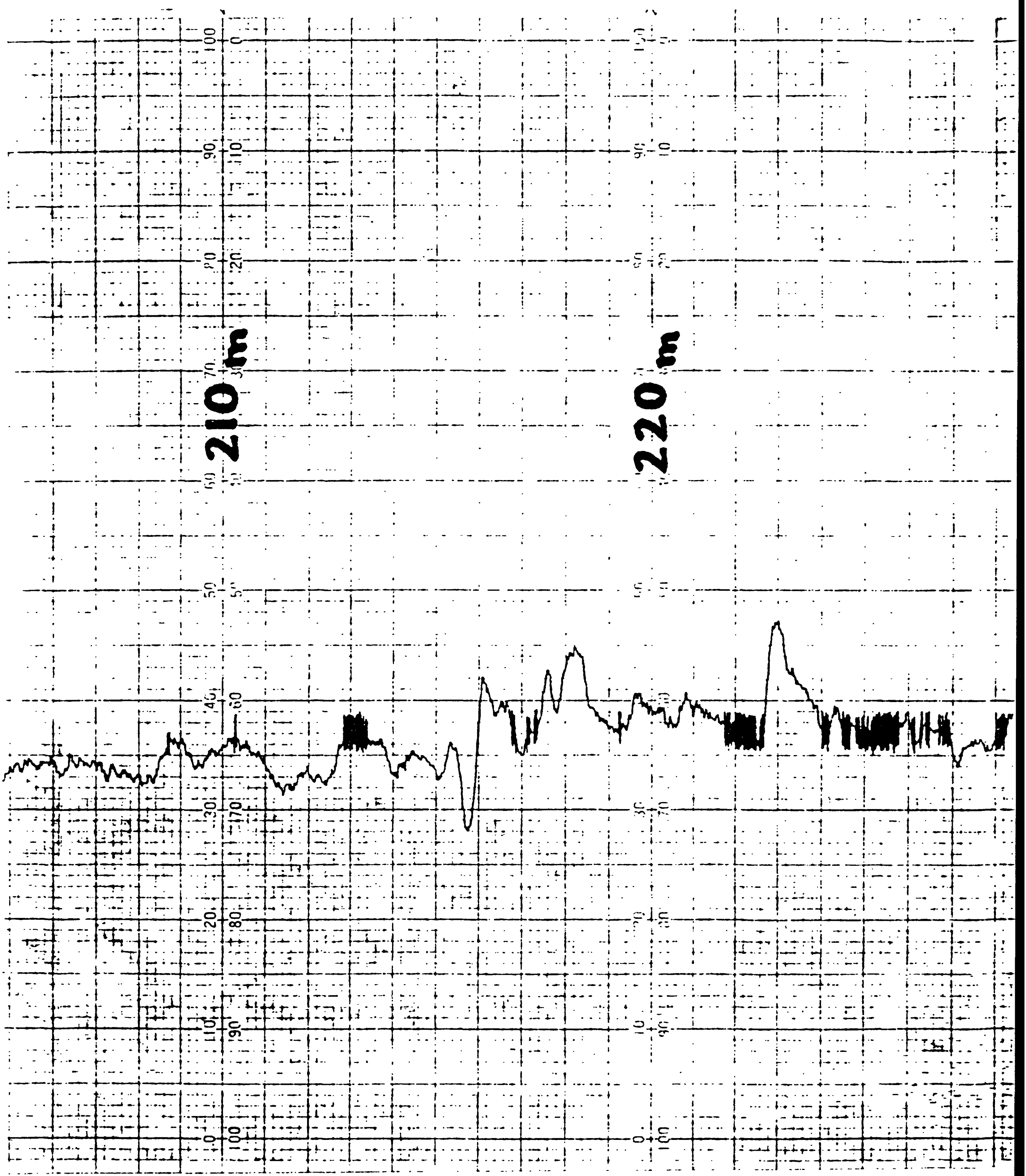
110m
120m

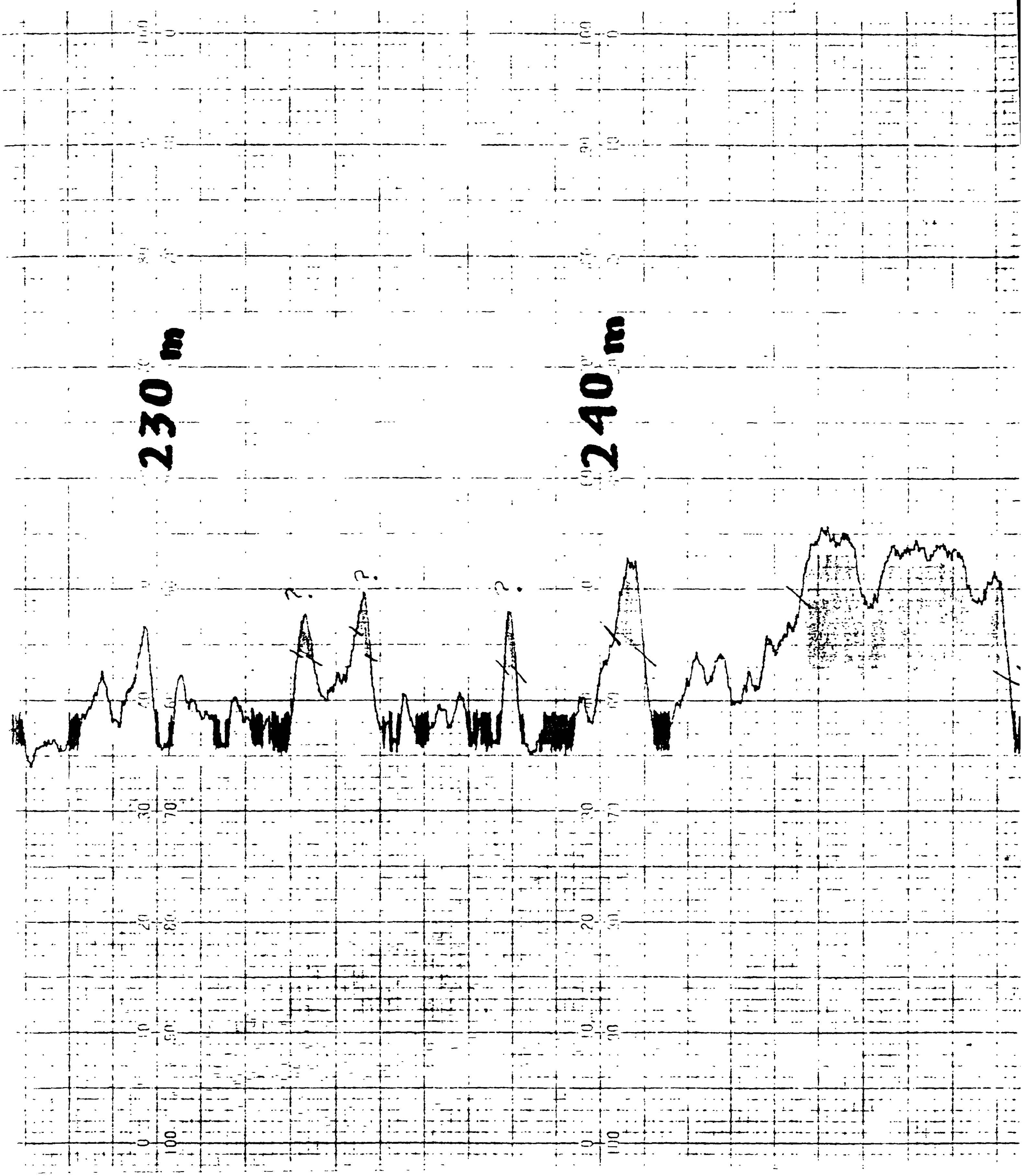

130 m
140 m

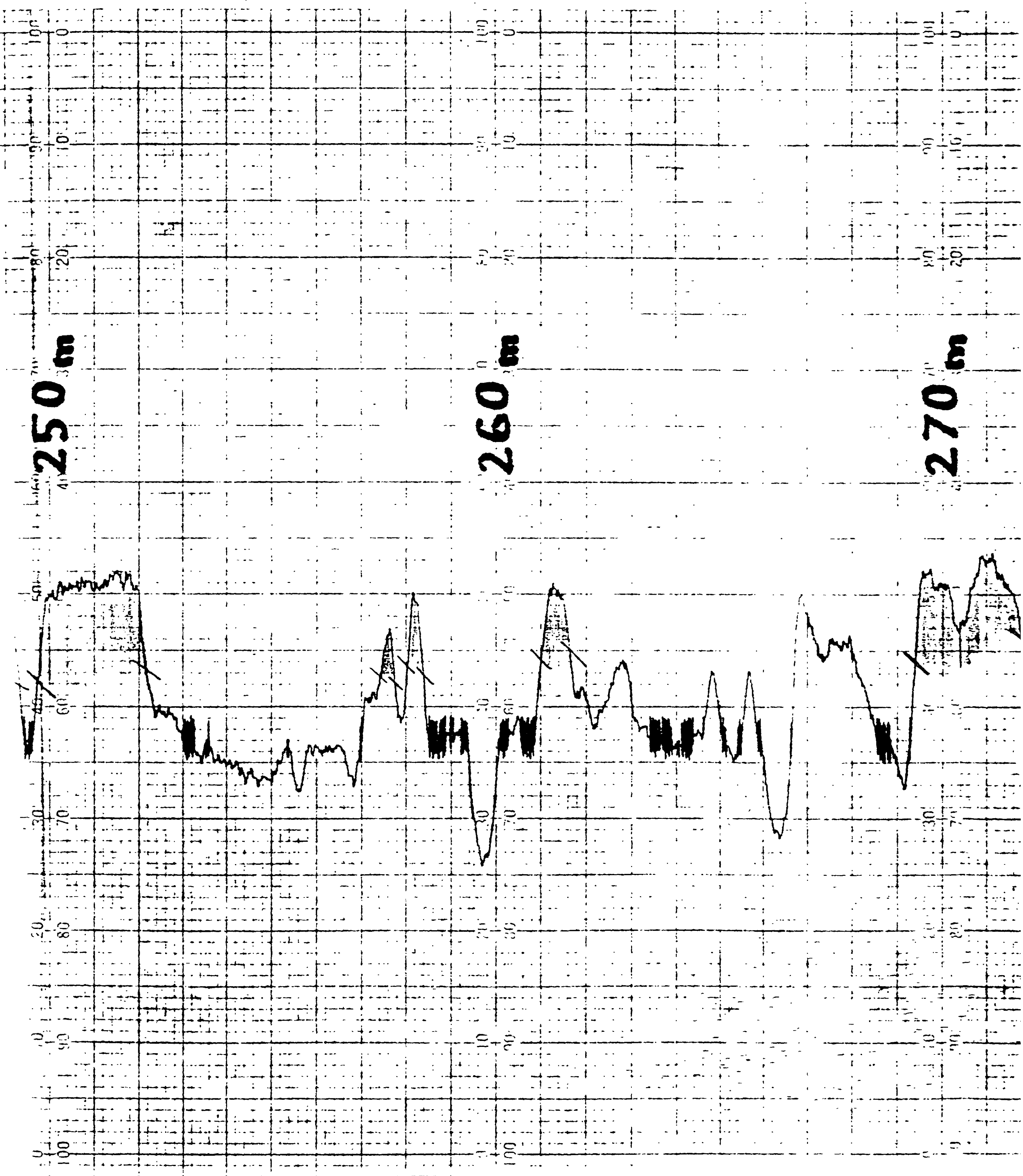

150 m
160 m

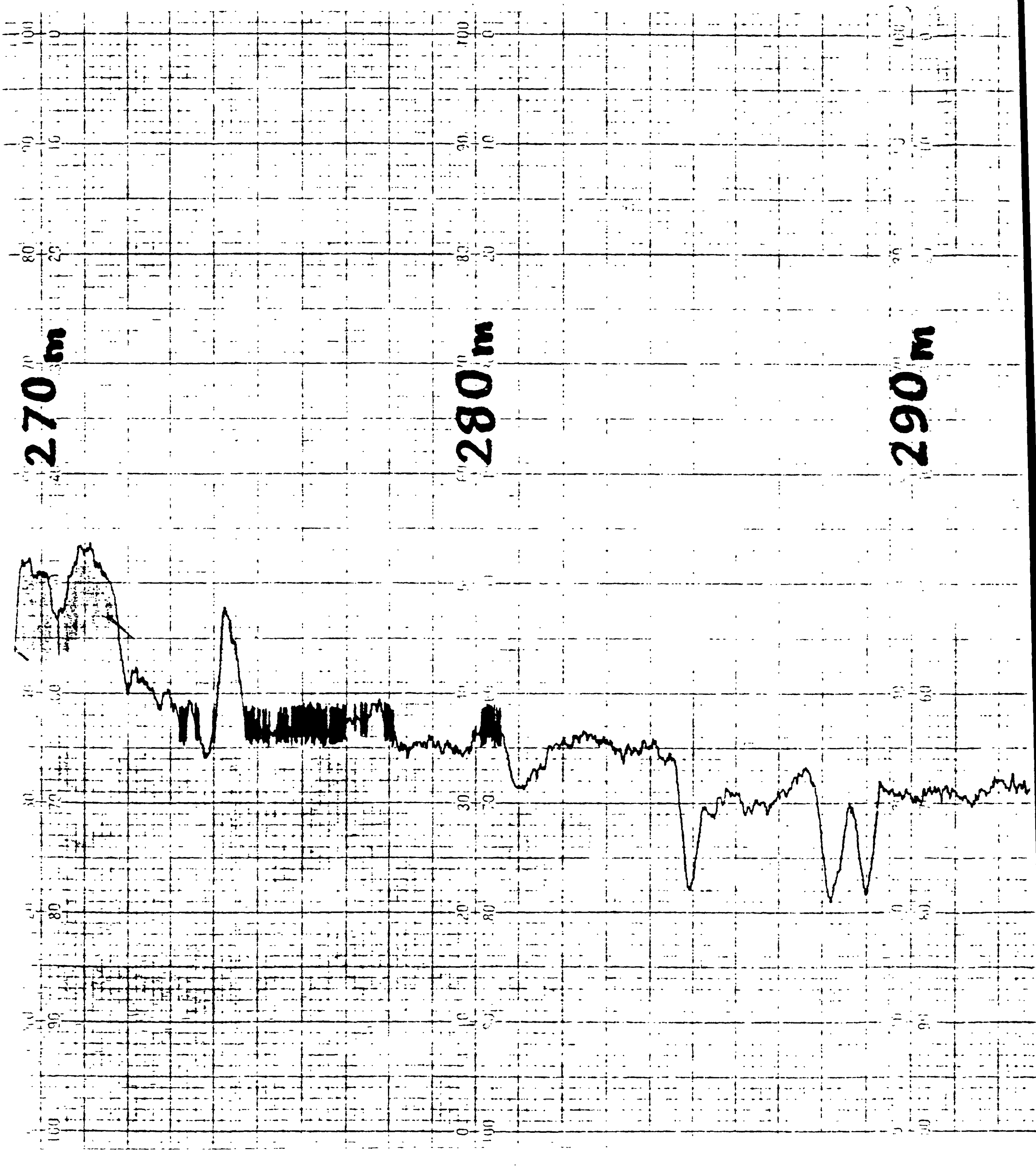

170 m
180 m
190 m

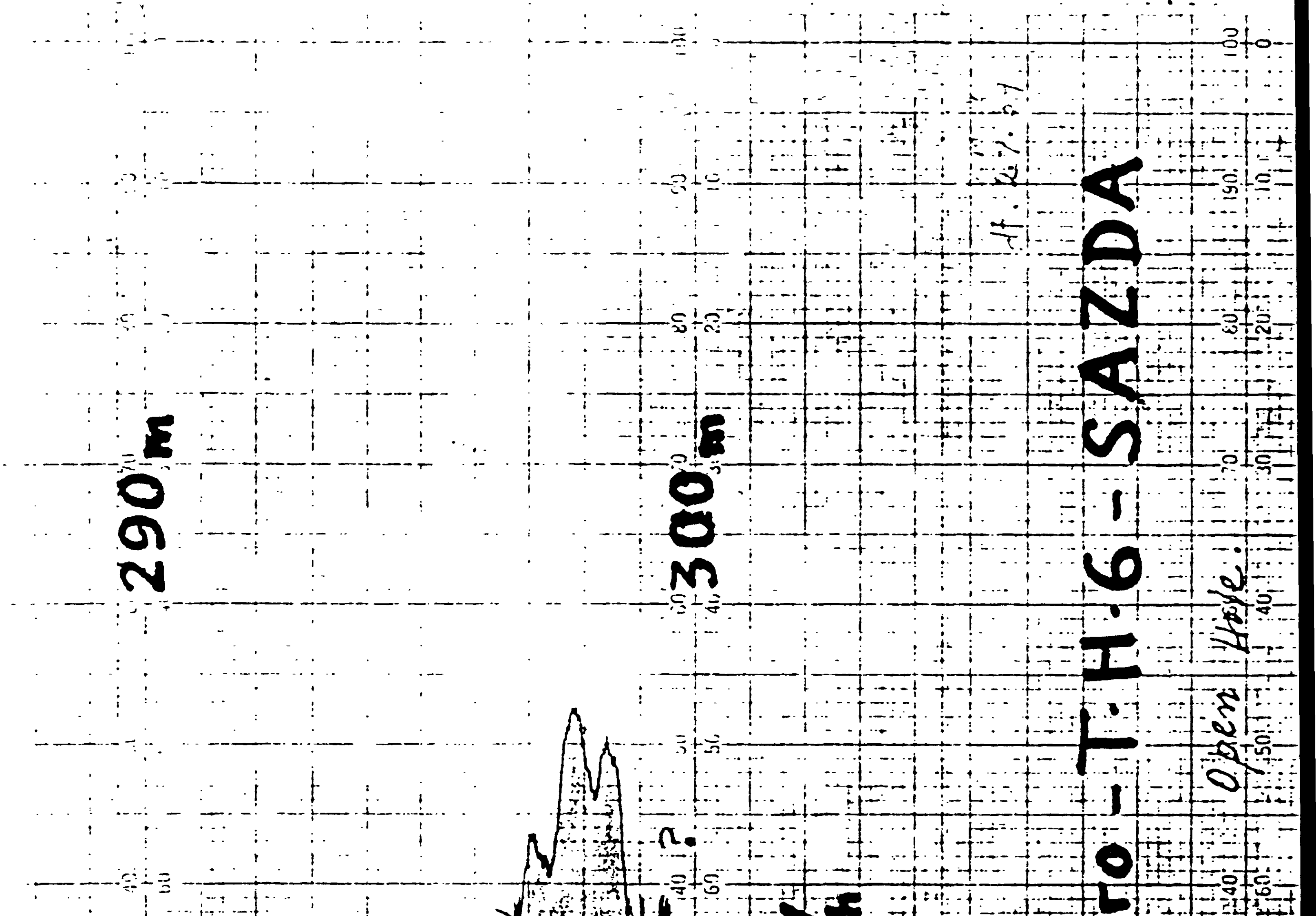

190 m
200 m


210 m
220 m


230 m
240 m


250 m
260 m
270 m


270m
280m
290m


290m
300m
?
4Pi Density
2000 cps/Inch
1% Std. Dev.
Zero
Chhachro - T.H.6 - SAZDA
Open Hole