CHAPTER 2 GENERAL OUTLINE

2-1 The Investigated Area

2-1-1 Location and Extent of the Investigated Area (Fig. 1)

The investigated area, spreading over 26 square kilometres of the block of PMDC licences, falls almost in the centre of Lakhra coal field, which is reported to extend for 40 and 12 kilometres in north-south and east-west directions respectively. It is located to the northwest of Hyderabad and is about 6 kilometres in east-west and 4 kilometres in north-south directions.

The area was selected for detailed exploration in 1979 as it enjoyed favourable geological and mining conditions reported by PMDC on the basis of data collected through 22 drill holes. It occupies about half of the area of PMDC's block from its centre to western boundary. Further exploration in the remaining part of the block would be carriedout to analyse the geological and mining conditions and for estimating quality and quantity of coal during the development of coal in the investigated area. Number of 50 drill holes executed in the area was determined by due consideration of both period of drilling, and data required for analysis of geological and mining conditions beside quality and quantity of coal.

2-1-2 Access

Lakhra coal field lies to the west of Petaro-Khanot-Manjhand section of Kotri-Habib Kot railwayline and Indus highway. It is accessible by truckable unmetalled roads commencing from Indus highway at Aliabad, about one mile south of Khanot, and near Khanot railway station. The unmetalled roads were constructed and are maintained by private companies mining coal from about 30 openings to the south of the investigated area for transporting water to the mines from Indus river and transport of coal through trucks.

The investigated area is about 21 kilometres by road from Khanot. It is easily approachable by four-wheel driven vehicles and bears a net-work of truckable roads. It is at a road distance of 80 kilometres from Hyderabad, and 217 kilometres from Karachi.

2-1-3 Topography and Climate (Figs. 5 and 6)

The investigated area consists of flat-topped hills comprising of Laki limestone eroded at places to give rise to small and narrow valleys exposing older rocks. About half of the western part is flat with gentle undulations at places. Eastern part of the area is traversed by Kath Butthi stream and its tributaries, which dissect the limestone giving rise to valleys and isolated hills with flat tops, and fairly rugged topography. Ranikot formation and Basal Laki laterite are exposed along the slopes and bottoms of valleys. Relief of the area is low. Drill-hole JT33 at the highest altitude is located at 141.530 metres, and lowest in case of JT49 at 112.092 metres above sea-level.

Save few low lying areas on the hill tops and valleys, the area is generally barren. There are some shrubs and bushes. However, trees are rare, and this area looks like a desert of rocks before monsoon rains.

During long summers from March to October, temperature during day time is very high

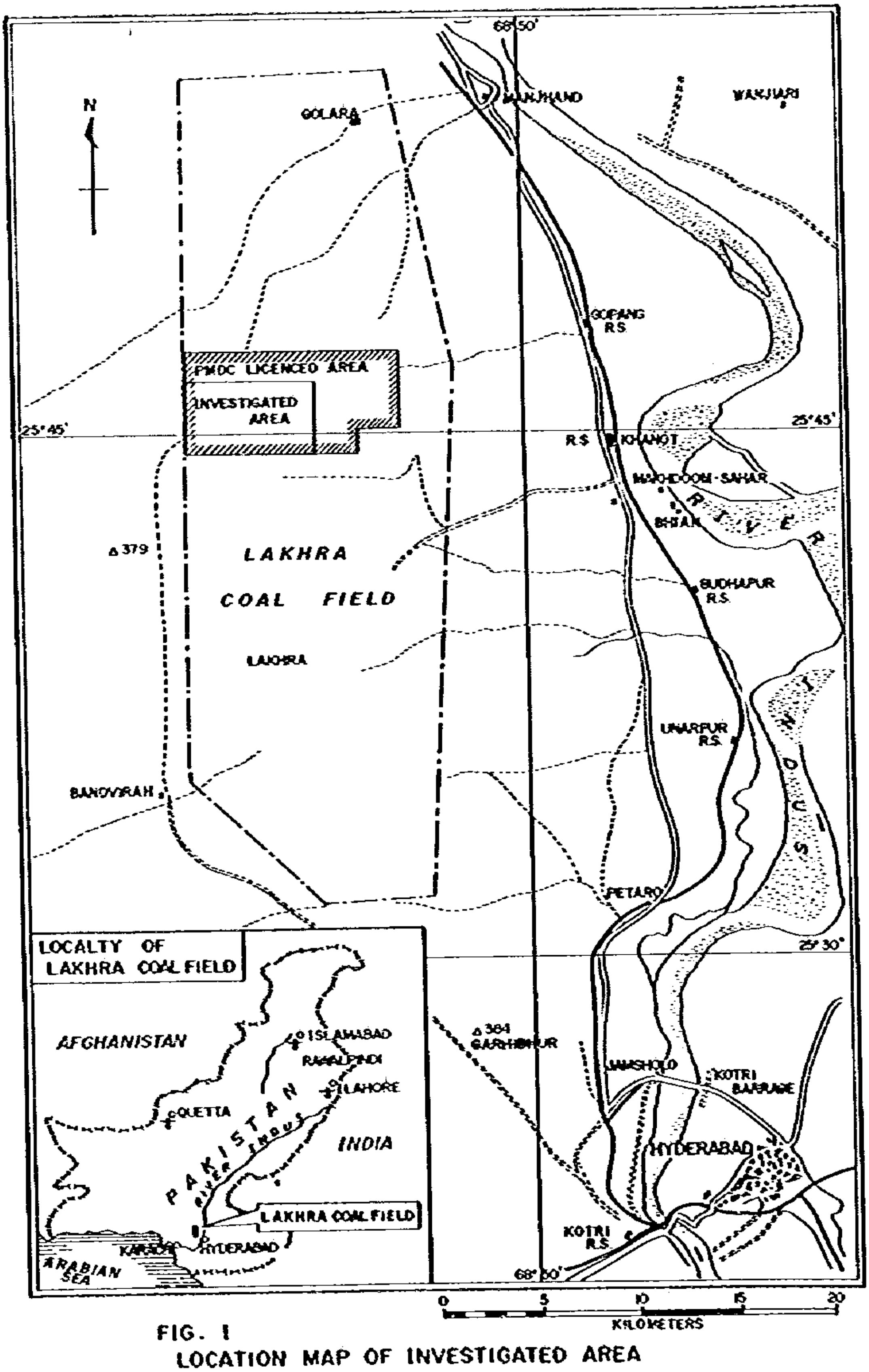
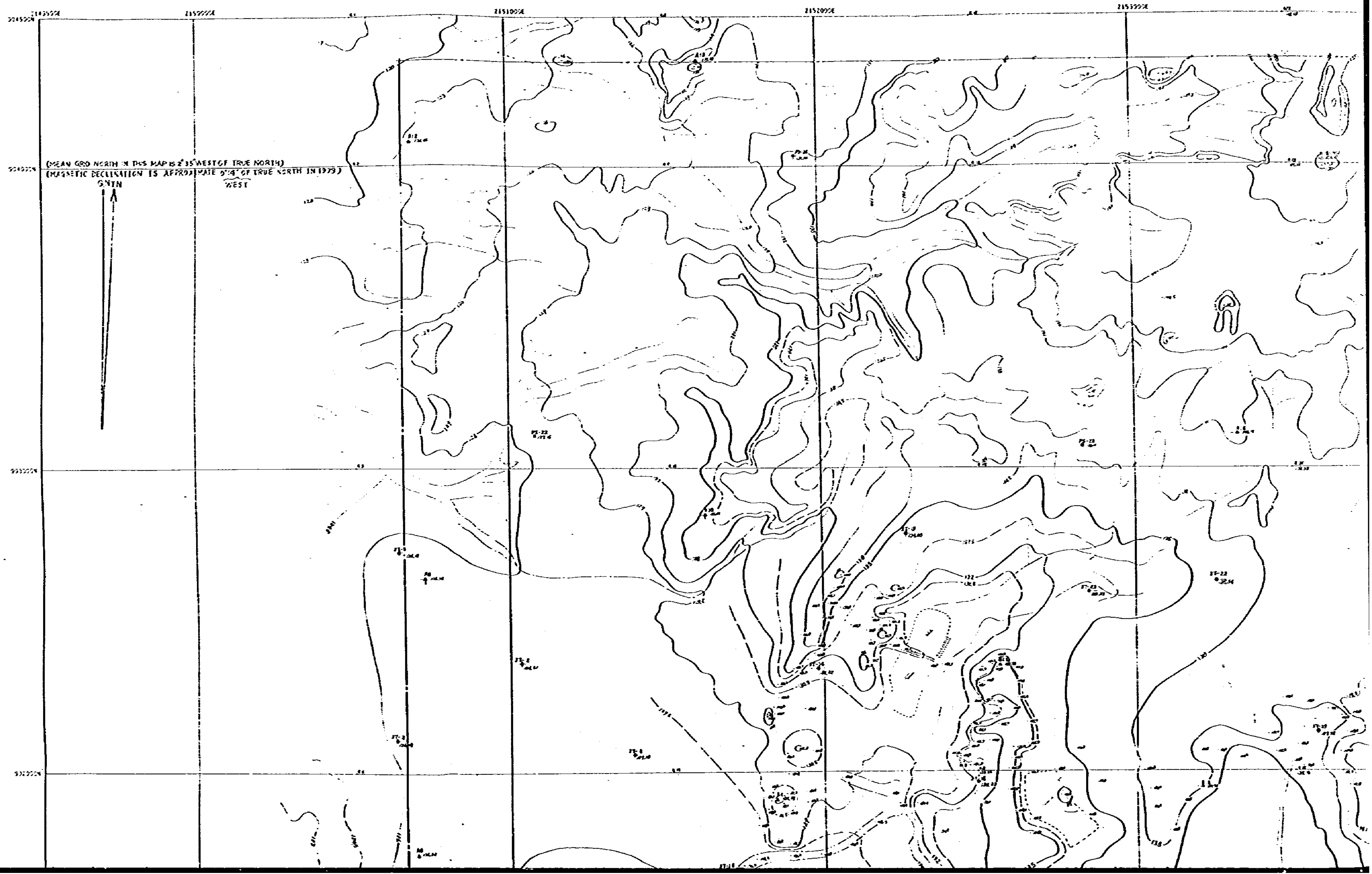
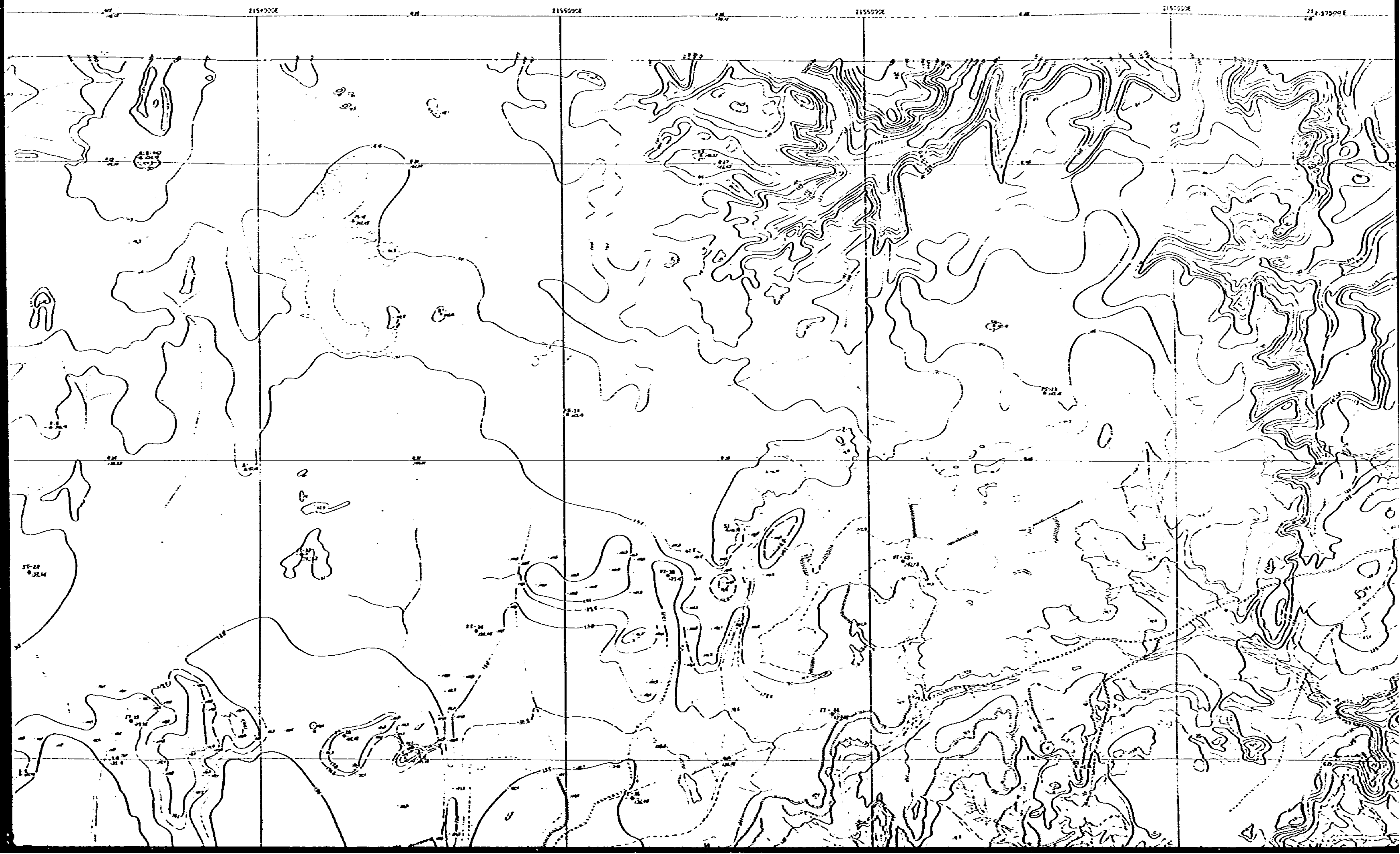


FIG. 1
LOCATION MAP OF INVESTIGATED AREA


(MEAN GRID NORTH IN THIS MAP IS 2°35' WEST OF TRUE NORTH)
(MAGNETIC DECLINATION IS APPROXIMATE 0°14' OF TRUE NORTH IN 1979)
GN TN
WEST



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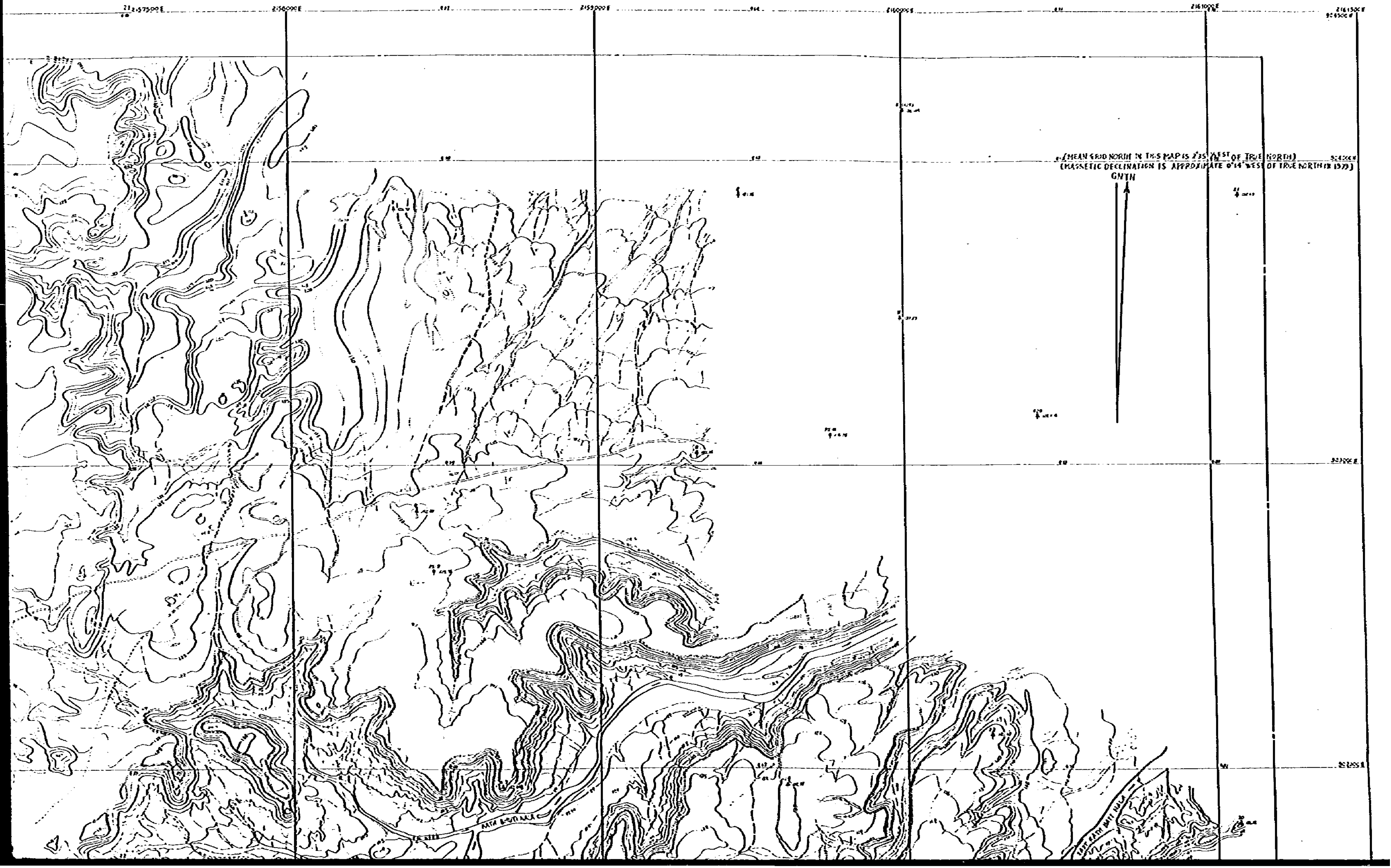
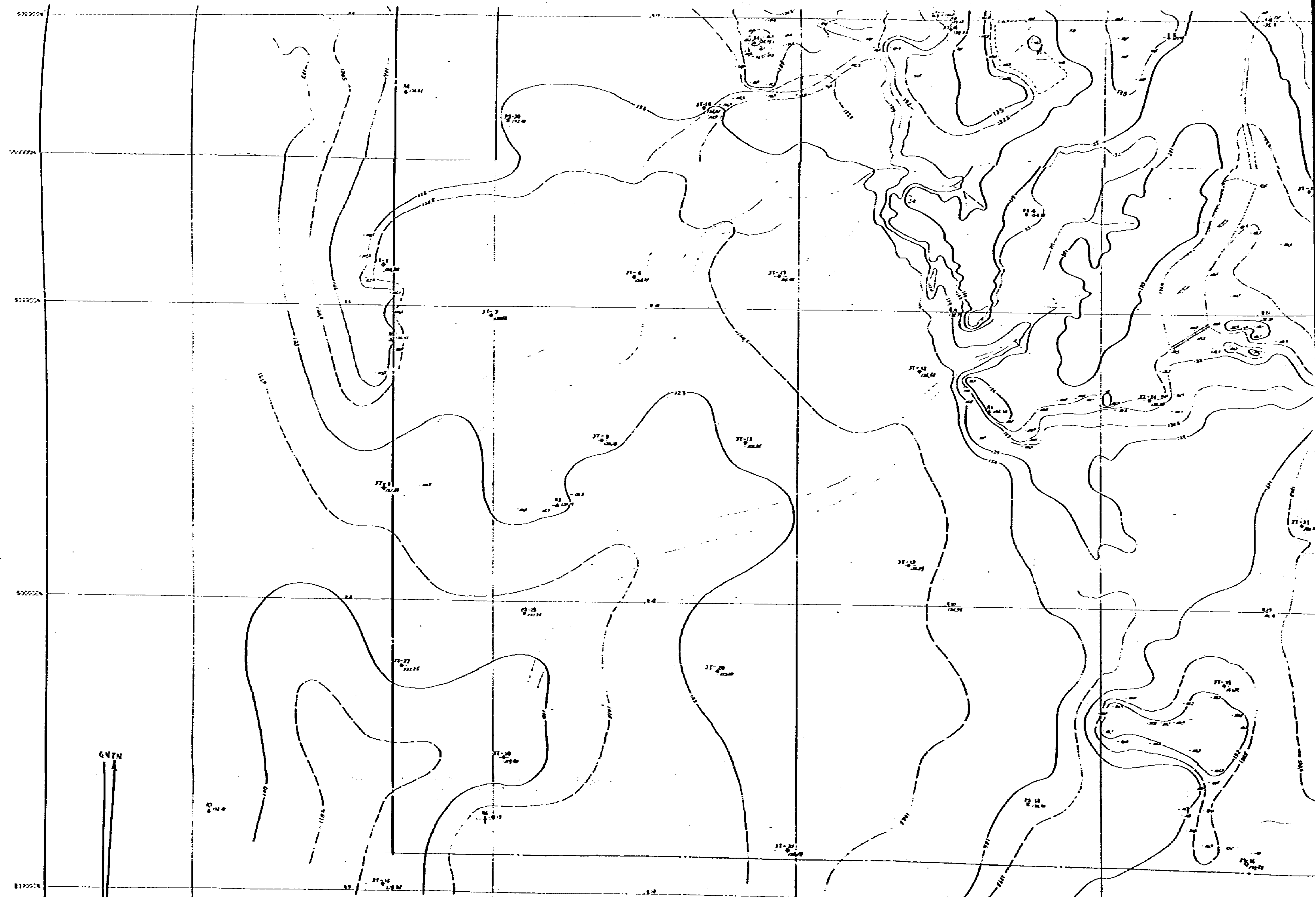

(MEAN GRID NORTH IN THIS MAP IS 2°35' WEST OF TRUE NORTH)
(MAGNETIC DECLINATION IS APPROXIMATE 0°14' WEST OF TRUE NORTH IN 1979)
GN TN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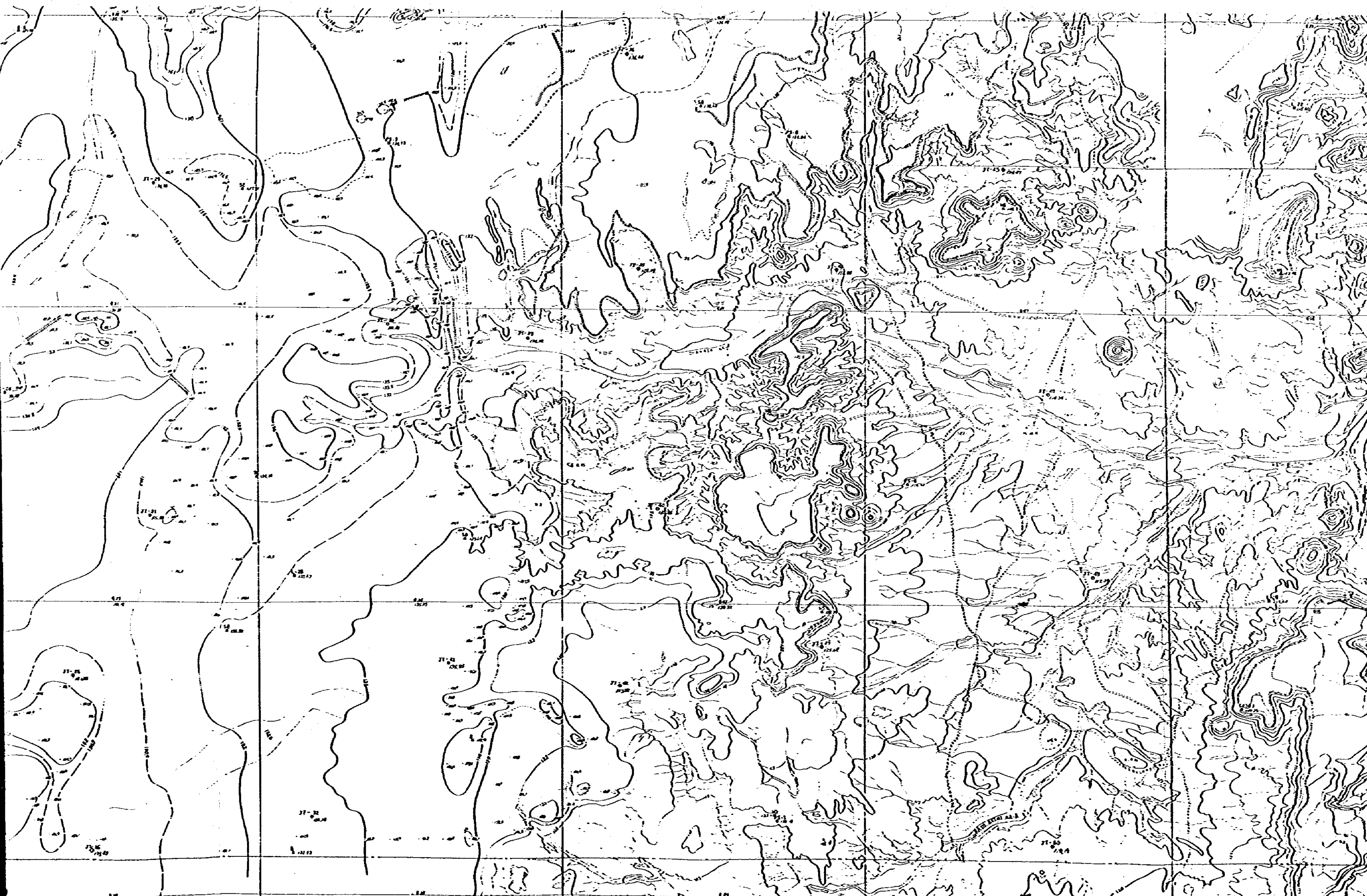
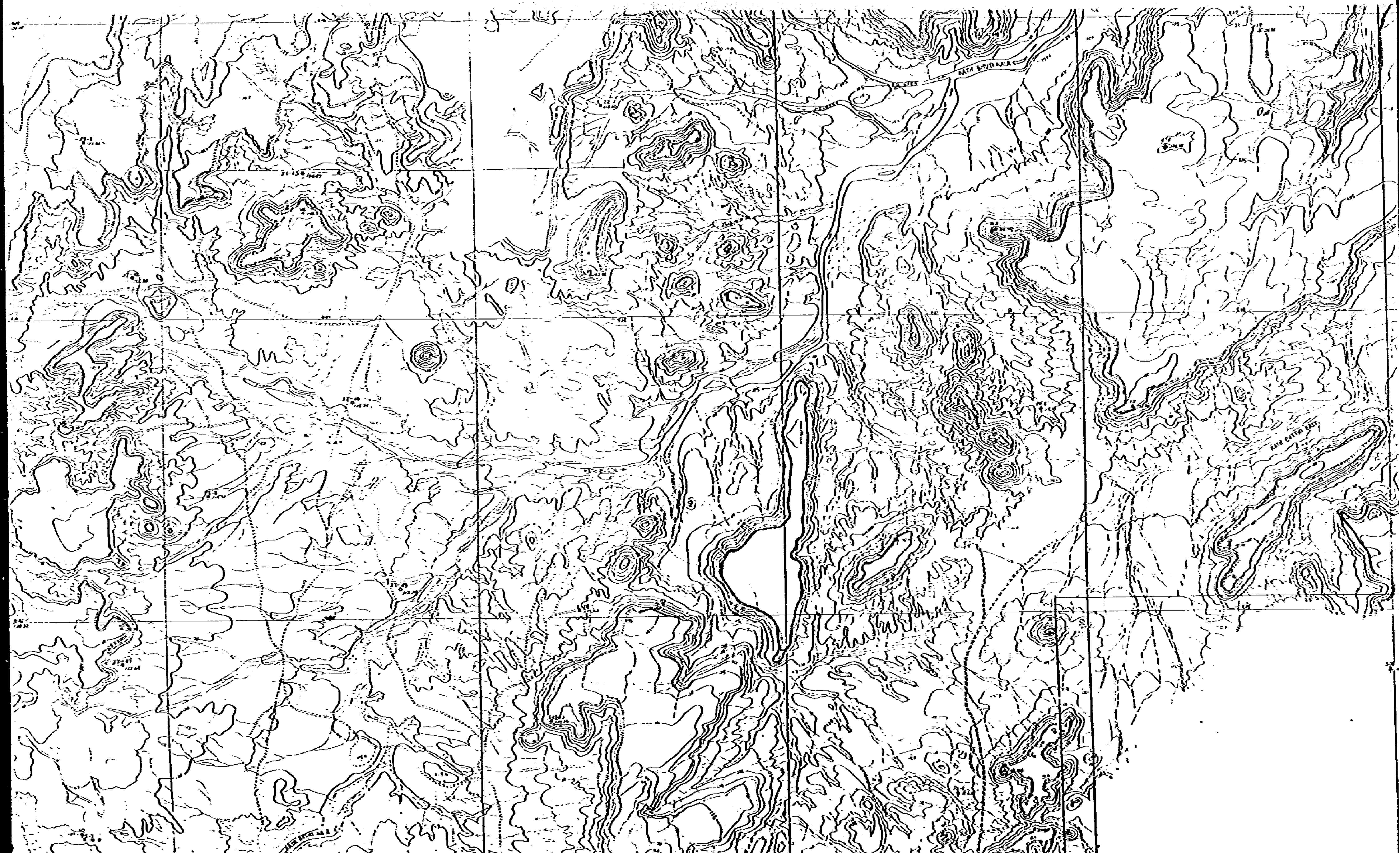




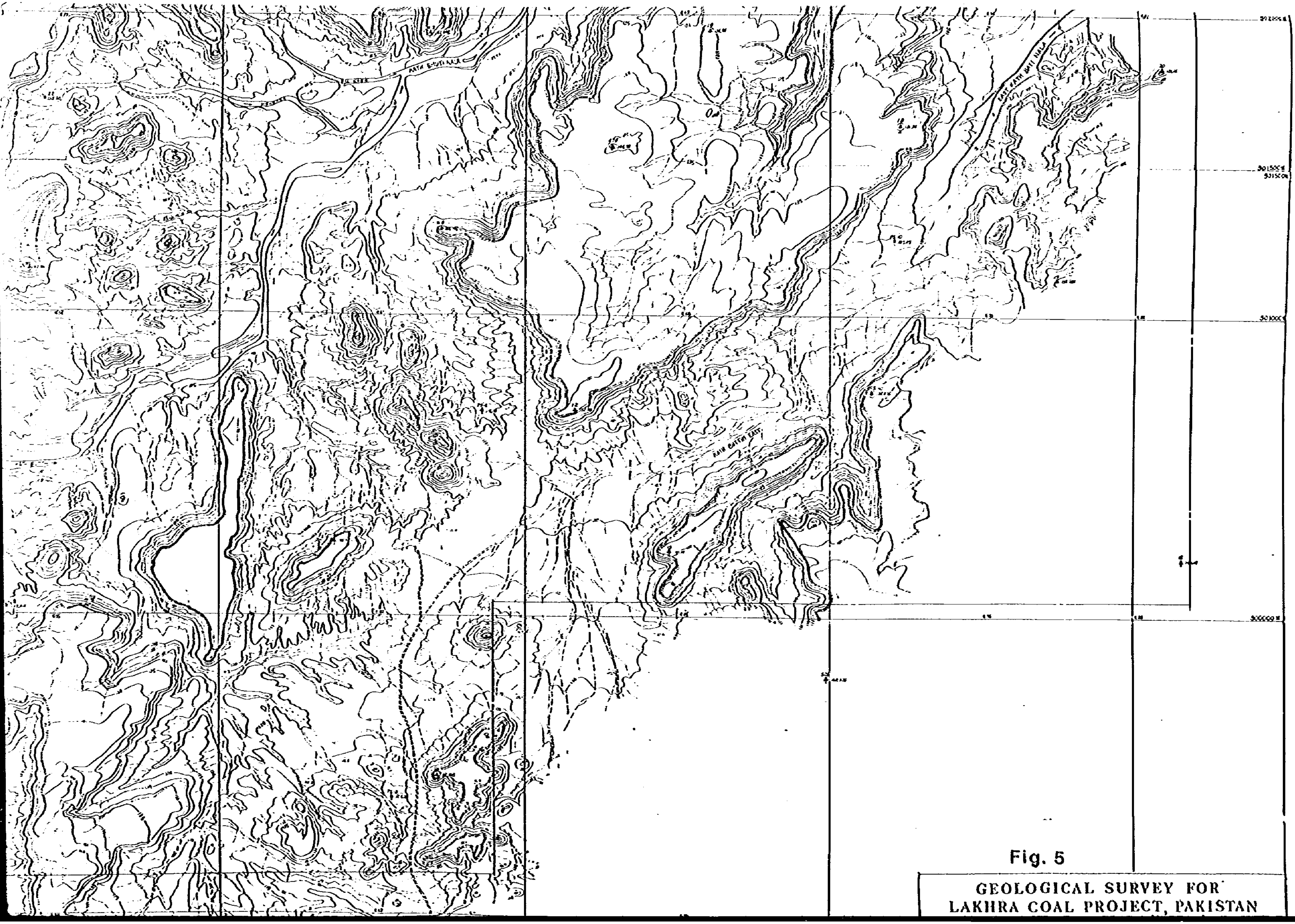
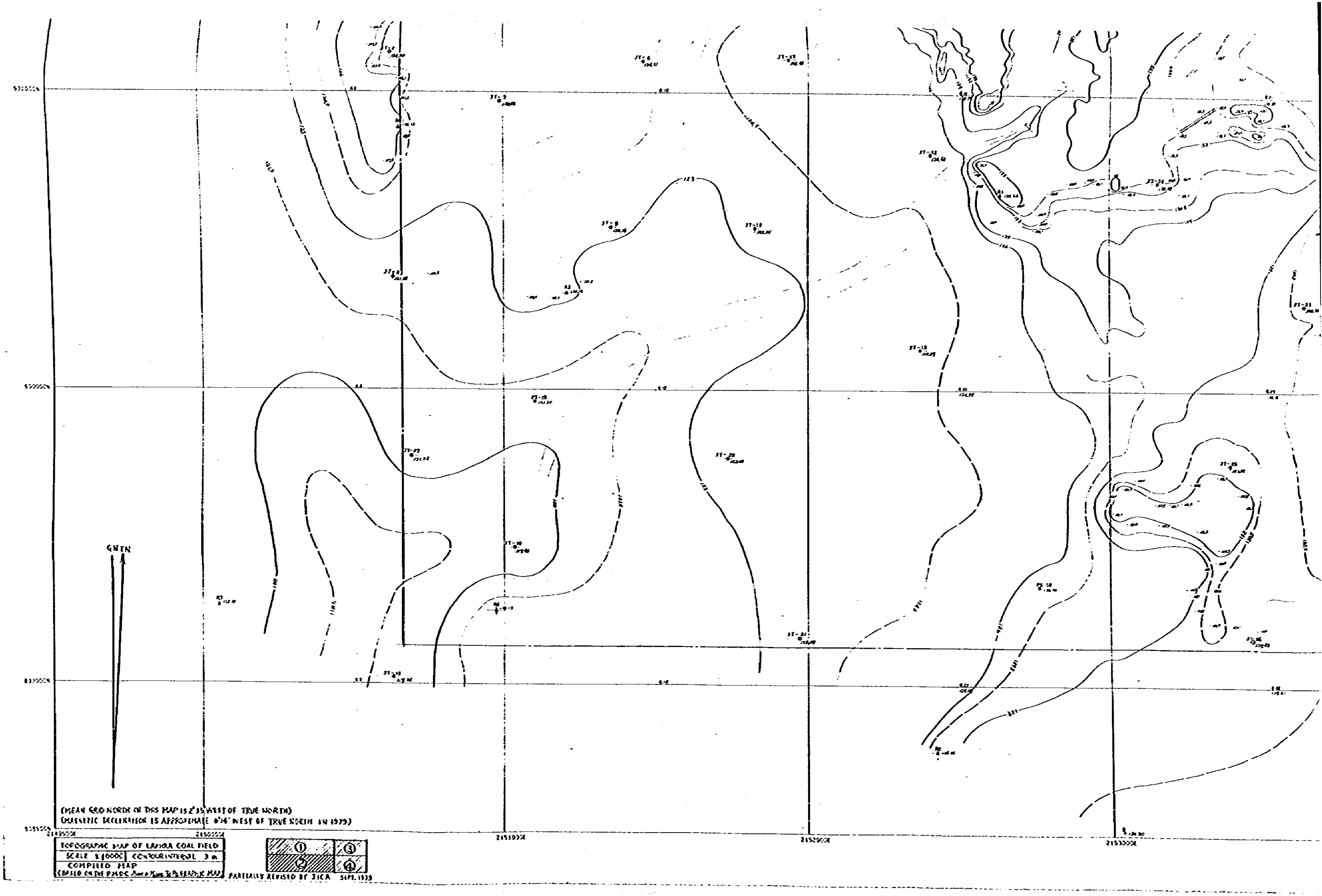
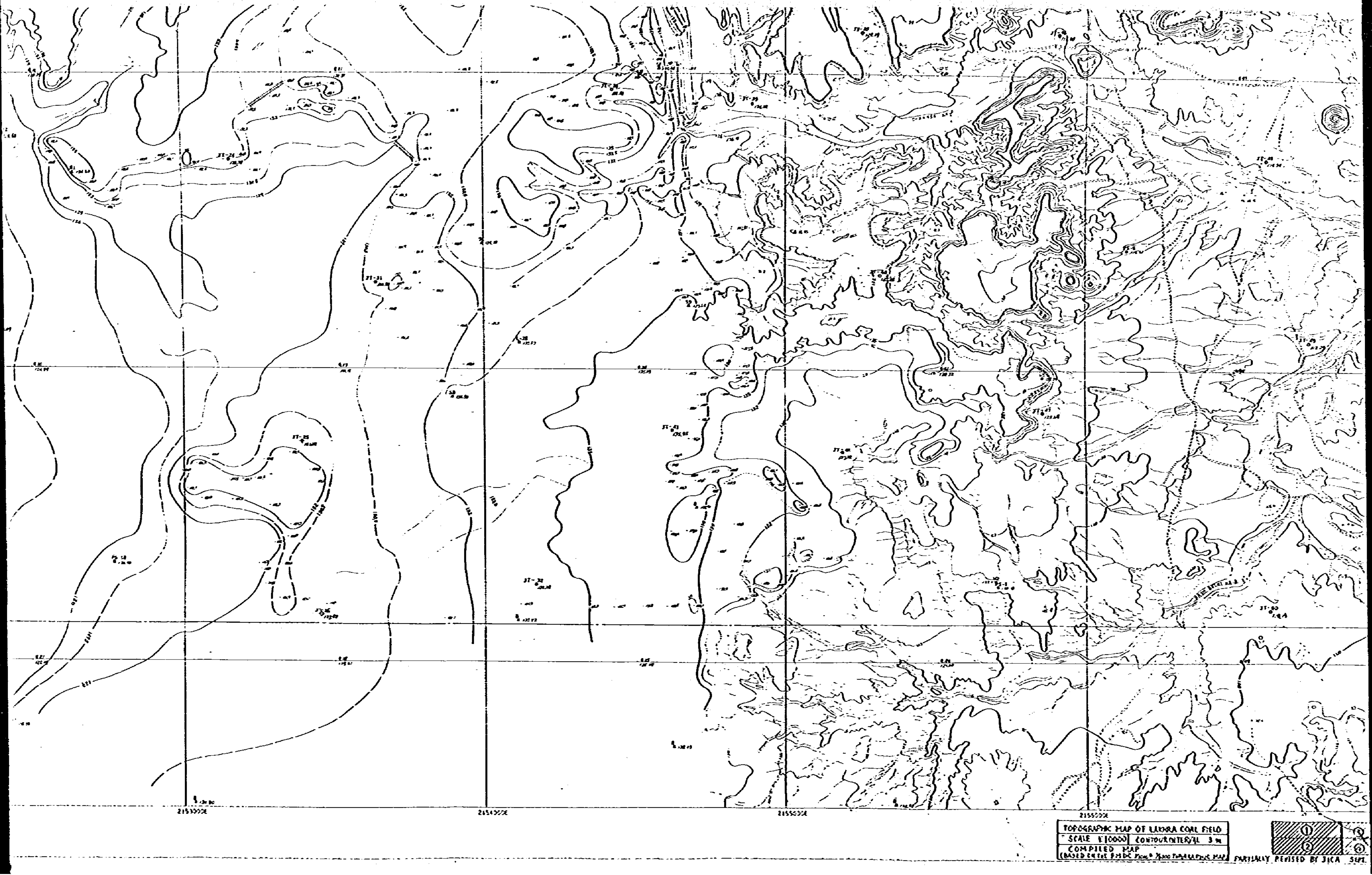


Fig. 5

GEOLOGICAL SURVEY FOR
LAKHRA COAL PROJECT, PAKISTAN



GN TN
(MEAN GRID NORTH OF THIS MAP IS 2°35' WEST OF TRUE NORTH)
(MAGNETIC DECLINATION IS APPROXIMATE 0°54' WEST OF TRUE NORTH IN 1979)
TOPOGRAPHIC MAP OF LAKHRA COAL FIELD
CONTOUR INTERVAL 3 m
COMPILED MAP
PARTIALLY REVISED BY JICA SEPT. 1979


TOPOGRAPHIC MAP OF LAKHRA COAL FIELD
SCALE 1:10000
CONTOUR INTERVAL 3 m
COMPILED MAP
PARTIALLY REVISED BY JICA
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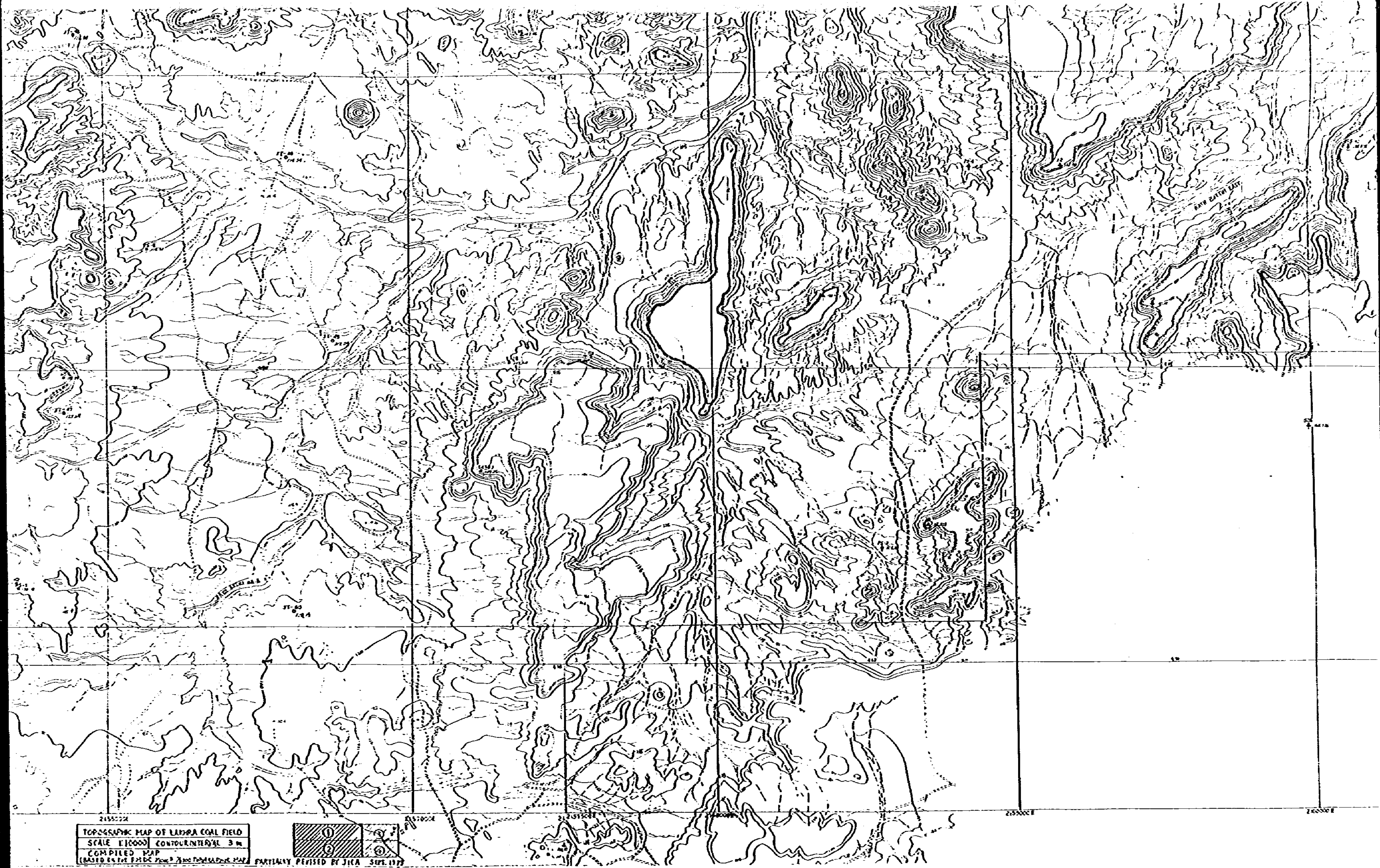

TOPOGRAPHIC MAP OF LAKHRA COAL FIELD
SCALE 1:10000
CONTOUR INTERVAL 3 m
COMPILED MAP
PARTIALLY REVISED BY JICA

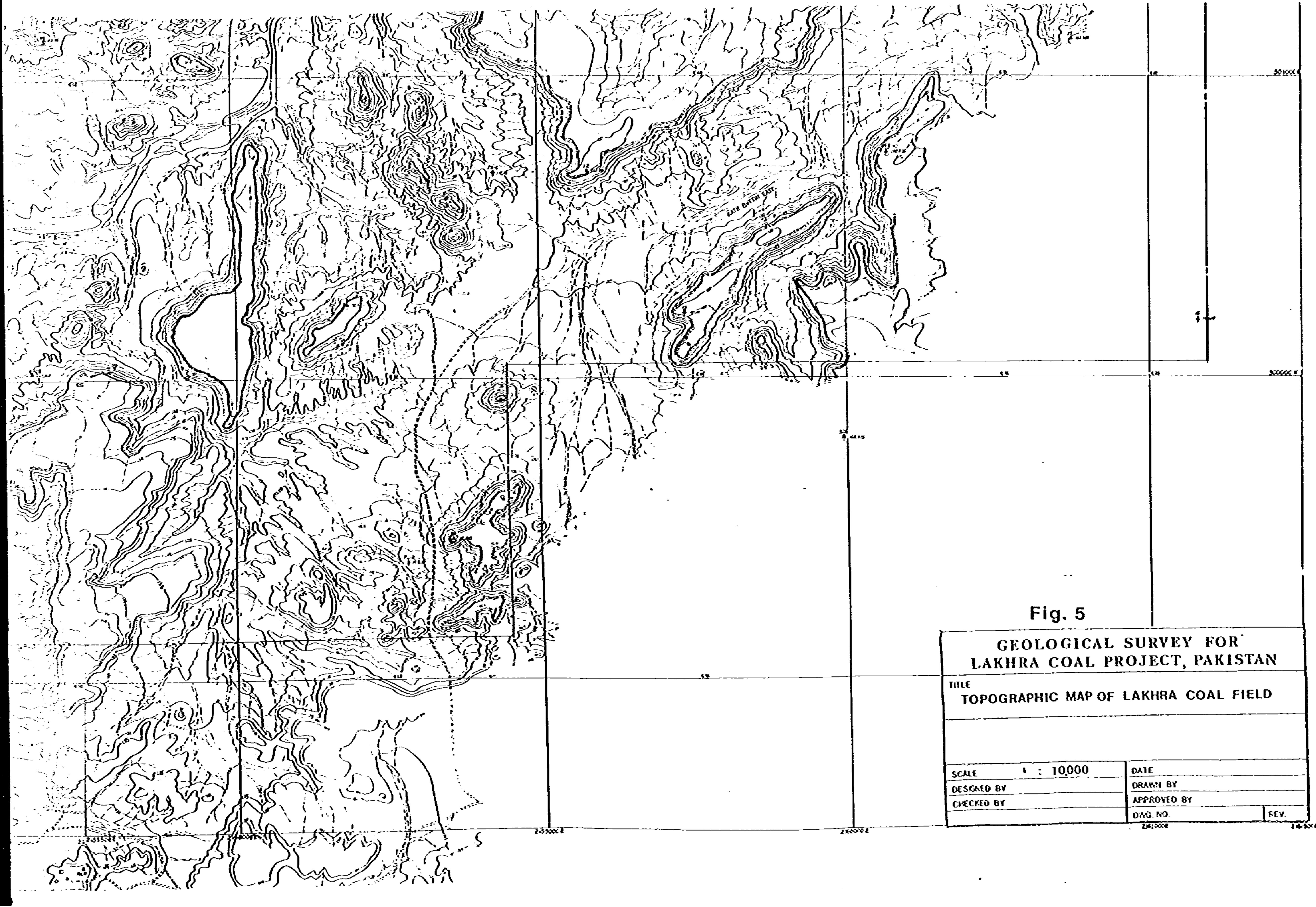


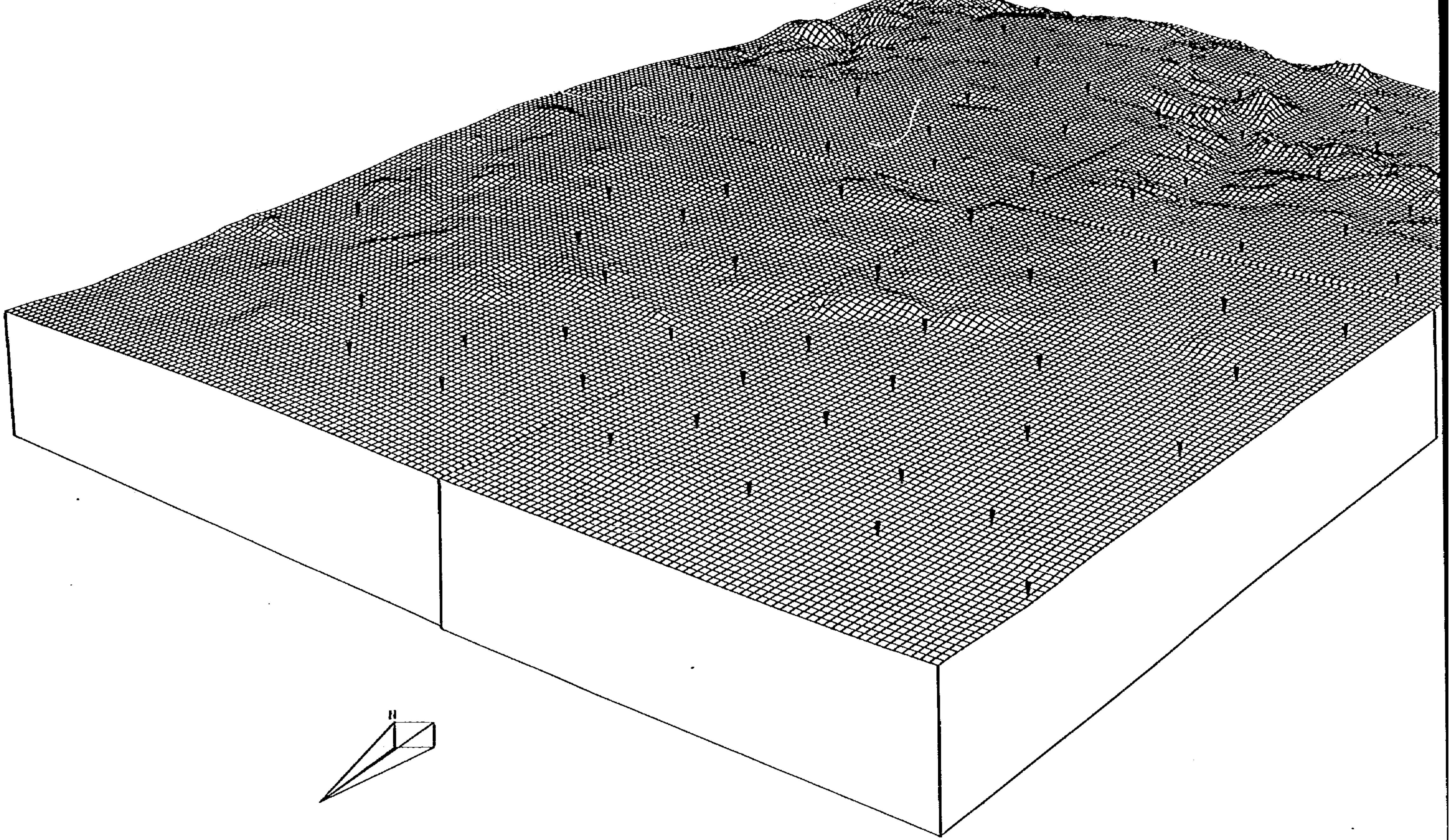
Fig. 5

GEOLOGICAL SURVEY FOR LAKHRA COAL PROJECT, PAKISTAN

TITLE

TOPOGRAPHIC MAP OF LAKHRA COAL FIELD

SCALE 1 : 10,000	DATE		
DESIGNED BY	DRAWN BY		
CHECKED BY	APPROVED BY		
	DWG. NO.		REV.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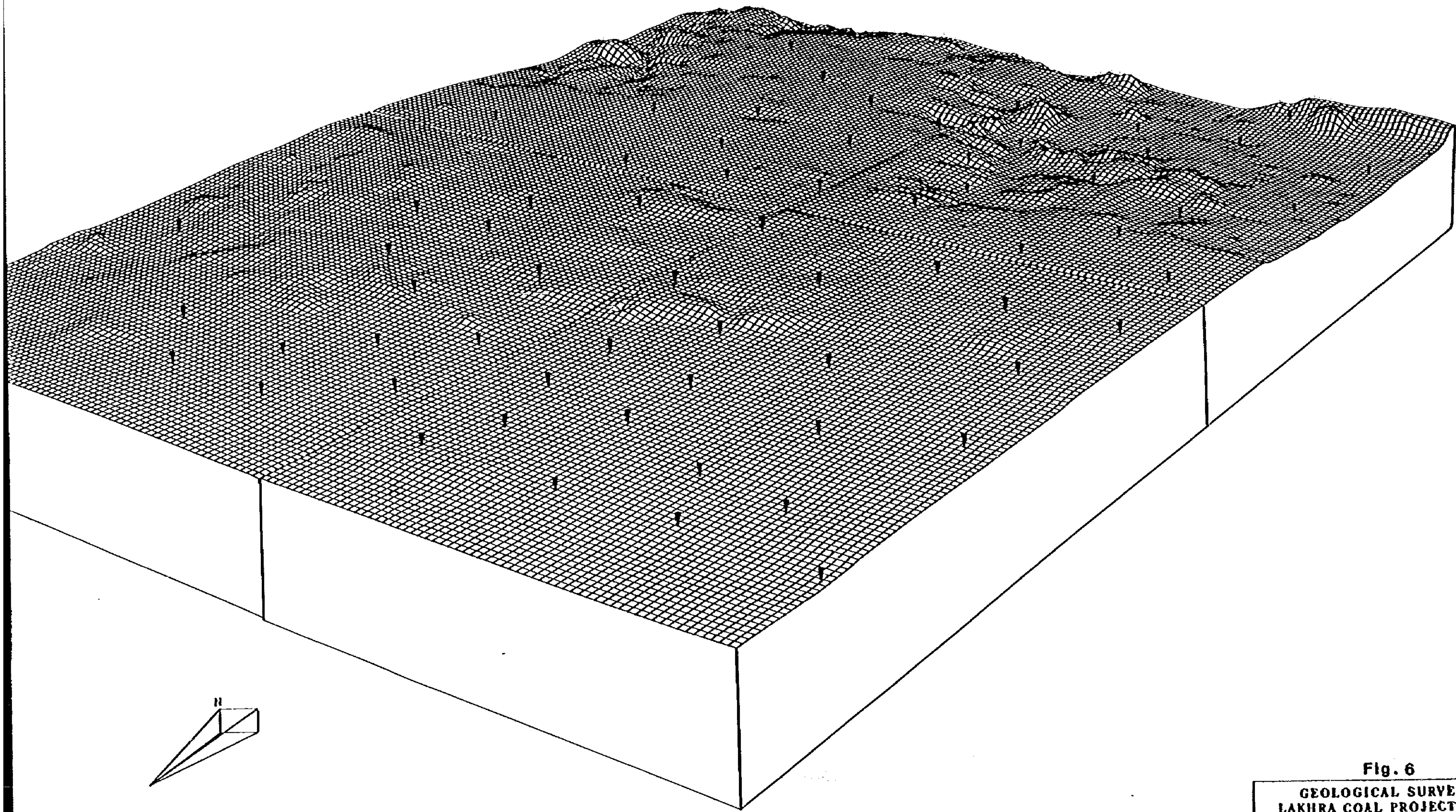


Fig. 6

GEOLOGICAL SURVEY FOR LAKHRA COAL PROJECT, PAKISTAN	
TITLE BIRD'S EYE VIEW OF THE INVESTIGATED AREA	
SCALE	DATE
DESIGNED BY	DRAWN BY
CHECKED BY	APPROVED BY
	DWG NO / REV.

exceeding ever 50 degrees centigrade on quite a few days. During the first week of August it rained in the area making it green with grass, bushes and shrubs. Many nomads moved in alongwith their cattle. They remained in their areas as long as the rain-water lasted in ponds. During this period they plough the depressions soaked with rain water and tend the cattle.

The climate in November became mild to the extent that it appeared pleasant without air-conditioners even during day time.

The rains mentioned above were torrential. They were exceptionally heavy. The dried nonperennial streams swoll with water rushing furiously to the river Indus. The Indus highway was washed away partially/completely at many places and four bridges collapsed between Hyderabad and Khanot.

2-2 Previous Investigations

2-2-1 Pre 1976 Work

Coal in the area was reported as early as 1855, but the systematic surveying commenced from eighteen seventies. Coal mining in the area commenced in Pre-Independence days and is continuing on a small scale with regular mining and gradual increase in production from early sixties. Presently, there are 8 private coal mining companies producing about 180,000 tonnes of coal per annum.

Geological Survey of Pakistan investigated the Lakhra coal field in early sixties, and based on 28 drill holes executed over an area of about 205 square kilometers reported 240 million tonnes of coal of which 21.9 million tonnes were considered as proved reserves.

Following this WPIDC, Lurgi, Polish Consultants, JCI and CIDA have been involved in the evaluation of coal deposits, industrial tests for determining large scale commercial uses, and feasibility studies for mining and coal fired power plant.

2-2-2 Geological Work by PMDC

Geological investigations including mapping, analysis of structure, evaluation of coal, etc.; surveying including plotting of topography on large scale, and drilling at 19 sites have been carriedout by PMDC in the block of licences measuring 52 square kilometres. Results of the work have been detailed in the geological report on part of Lakhra coal field, near Khanot, district Dadu, Sind submitted in 1976. Following is the summarized description of the work;–

Regional mapping over 1380 square kilometres on 1:50,000 scale covering whole of Lakhra coal field and adjacent areas, detailed mapping on photogrammetric base maps on 1:12,000 and 1:6,000 scale covering areas held by private parties and most of the PMDC's block of licences, and topogeological mapping on topographic maps on 1:5,000 scale prepared by surveying 34.11 square kilometres of which 22.69 square kilometres belong to the block and cover part of the area investigated by JICA.

Drilling has been executed at 19 sites for a composite depth of 1844.927 metres from

December, 1975 to June, 1976, and geological analysis has been conducted together with the data of 3 holes drilled in the block by GSP previously. It is reported that the coal seams occur at 10 horizons. However, only three seams, namely, Lailian, Dhanwari and Kath are considered workable. Isopach maps of the workable seams have been prepared and based on these maps, the reserves of workable coal in situ have been estimated at 172.59 million tonnes assuming that the minimum workable thickness of coal is 0.75 metre. On the other hand, analytic data and results of tests by different agencies on samples collected from mines and through drilling, from time to time, incorporated in the report indicate that:—

The calorific value of coal ranges from 7,000 to 7,530 BTU/lb when wet (fresh sample from mine), and 10,000 to 11,230 BTU/lb in air dried samples. Sulphur content varies from 3 to 16 percent. The coals are classified as lignite A to sub-bituminous C in rank. They are non-coking and non-caking. They can be mined in large lumps, which lose moisture on exposure to surface and crumble down. They are liable to spontaneous combustion.

Exposed rocks in the area are Ranikot group of Paleocene age, Laki group belonging to Eocene epoch, Manchar formation of Pliocene, and thin sporadic Quaternary deposits.

Ranikot group is divided into Lower and Upper Ranikot formations. Upper part of the Lower Ranikot formation is impregnated with coal seams.

The mapped area consists of crestal part of a doubly plunging anticline with axis running north-south trending normal faults longitudinal to the structure. Unconformities exist between Ranikot and Laki groups, and between Manchar formation and older rocks.

The above said data and description have been used in the present report.

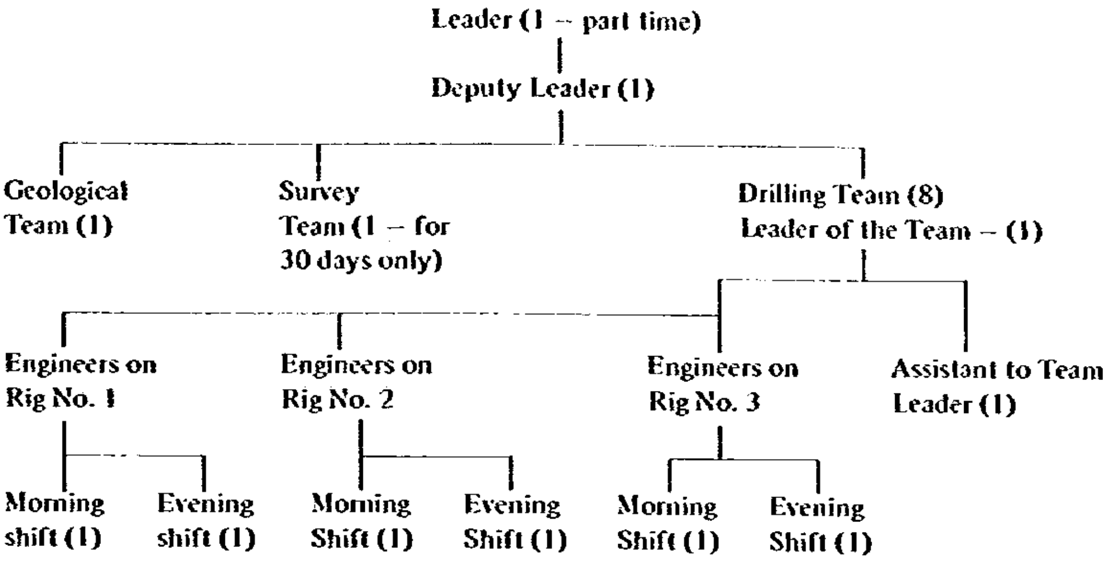
2-3 Present Exploration Work

2-3-1 Introduction

Most of the equipment such as drilling rigs, land cruisers, surveying instruments, etc. required for exploration work were imported by the JICA Mission from Japan.

Drilling was performed by drilling engineers with 3 drilling rigs on two shifts system. Geological and general surveys were undertaken on one shift system.

JICA Mission was organized as detailed below:–



(Numerals in brackets show number of personnel)

The land cruisers (three numbers brought from Japan were utilized for commuting service from base camp to sites, communication between sites, and transport of materials. Wireless equipment and walkie-talkies were also provided.

2-3-2 Drilling Work

(1) Drilling Rigs

Main items of drilling equipment used as site are:–

(i)	Koken Hydraulic Feed Drilling Machine	RK-2	Engine 3T-90L	3 sets
(ii)	Koken Wire-line Pump	WL-MG-10	Engine NS-110C	3 sets
(iii)	Koken Hi-speed Mud Mixer	HM-250	Engine NS-65C	3 sets
(iv)	Koken Tripod Pipe Derrick	GPD-95		3 sets
(v)	Koken Wire-line Hoist	WLH-4	Engine NS-50C	3 sets
(vi)	Generator for Illumination	GR-2.2		3 sets
(vii)	Mud Tank	5 Tons-capacity		4 sets
(viii)	Bentonite, Ribonite, etc.			1 unit
(ix)	Other parts			1–3 units

Other items which were procured in Pakistan are as follows: –

Tank Lorries	2 nos.
Trucks	1–3 nos.
Water tanks	3 sets

(2) Results of Drilling Work

Table 4 Summary of Drilling Work

Month	Nos. of shifts	Nos. of Drill-holes	Composite Drilling depth (m)	Average depth (m)	Recovery of core %	Nos. of holes barren or with thin coal
June	6	–	–	–	–	–
July	54	8	791.26	98.91	76	0
Aug.	34	5	437.85	87.57	79	2
Sept.	52	12	1,118.60	93.22	76	4
Oct.	74	15	1,690.10	112.67	67	0
Nov.	54	10	1,165.25	116.25	62	2
Total	274	50	5,203.06	104.06	71	8

Drilling has been executed at 50 sites for a composite depth of 5,2 03.06 metres to prove the coal deposits. Depth of drill holes ranges from 71.15 to 143.25 metres.

Limestone was mostly drilled with tri-cone bit 4 inches in diameter. The hole was then cased with pipe of 97 mm diameter to prevent water loss. Following this the remaining drilling of the hole was conducted using NQ Bortz bit of 70 mm diameter by the 'wire-line working method'. NQ core barrel was used for collecting core, but the core recovery achieved is 71 percent due to loose and soft sandstone zones in the formation. In addition to inserting the casing pipe, bentonite, Ribonite etc. were employed to control the water loss.

Up to 16 coal seams, as in JT 39, were encountered during the course of drilling. Drill holes containing the coal seam(s) having more than one metre thickness are 39.8 drill holes (JT6, 11, 12, 13, 17, 18, 20 and 22) proved to be barren or contain very thin and insignificant coal seams.

2-3-3 Geological Investigations

After the logging of drilling cores at site, cores of coal seams and rock samples were packed for analyses and tests.

Columnar and geological sections have been prepared on 1:500 scale, and used in the interpretation of geologic structure. Columnar sections of coal seams have also been prepared on 1:50 scale. Efforts have been made to correlate the seams with the help of said sections, and topogeology has been investigated to some extent.

Detailed studies have been carriedout in Japan. Further work on correlation has been done based on the columnar sections of drill holes on 1:100 scale and those of coal seams on 1:50 scale. Coal and rock samples have been tested and analysed by various methods, and quality of coal and mining conditions have been determined. Based on the analytic data of coal samples, iso-ash maps, iso-calorific value maps and iso-sulphur maps have been prepared. Samples of some coal seams have been subjected to ultimate analyses, and their washability curves, ash fusion temperature and composition have been measured. Correlation diagrams between specific gravity and ash, ash and calorific value have been made.

Isopach maps of coal seams above 0.5 metre in thickness and structural contour maps have been prepared. Areas available for open-cut and underground mining have been delineated based on the studies mentioned above, and coal reserves have been calculated separately for both.

As a result of the present work, the coal seams in the investigated area appear to fall in two horizons namely, the Upper Coal-bearing Beds and Lower Coal-bearing Beds. The Upper Coal-bearing Beds contain all the important seams – Dhanwari, Lailian and Kath – reported by PMDC. Regardless of their size, shape, thickness and quality, 11 coal seams have been encountered in the Upper Coal-bearing Beds. These seams constitute 5 coal zones of which No. 3, No. 2 and No. 1 zones contain main workable coal and nearly correspond respectively to Dhanwari, Lailian and Kath seams. Theoretical reserves in situ have been estimated at about 79.8 million tonnes, and recoverable raw coal reserves at 53.7 million tonnes on the basis of strip ratio upto 1:15 by open-cut method, and by assuming minimum workable thickness of 0.75 metres and 0.50 metres for underground and open-cut mining respectively.

The Lower Coal-bearing Beds identified during the course of work lie 20 to 40 metres below zone No. 1 of the Upper Coal-bearing Beds. The Beds are 30 metres thick. They contain 8 coal seams, which fall in three zones – L1, L2 and L3. The seams are generally thin. Most important seam in the Beds is upto 0.92 metre thick. Also due to insufficient data these seams have not been evaluated.

Two barren areas have been located during the course of work. One of the areas falls in the western part. It runs north-south. The other located in the northern part runs east-west.

The coal seams and the strata are almost flat. They have been displaced in the central part of the investigated area by two pivotal normal faults. Block between the faults is down-thrown to form a graben with throws increasing towards south. The faults die-out in the investigated area when traced towards north.

2-3-4 Survey

Co-ordinates and elevations above sea-level of the grid-intersection points and proposed/executed 50 drill holes have been determined in the investigated area spreading over 26 square kilomtres. Further, for compiling the topographic base map of the area, supplementary survey has been carriedout.

The work has been accomplished jointly by Pakistani and Japanese surveyors. Surveying instruments used during the work are detailed in Table 5.

Table 5 Surveying Instruments

Item	Quantity	Particulars	
Theodolite	1	Japan	Nihon Kogaku K.K. NT-2
"	1	PMDC	Asahi Seimitsu Pentax
Compass	1	Japan	Ushikata K.K. Minimum Scale 1 degree
Other Instruments	1 set	Japan	5 metres Telescopic Staff, Eslon Tape 50m, other Tape
"		PMDC	3 metres Telescopic Staff

Following is the summary of work accomplished:–

(1) Determination of grid co-ordinates and elevations of drill holes (Table 6)
Number of drill holes: 50
Accuracy of direction angle from new point to known control point ±0°03'>
Accuracy of co-ordinates ±30 cm>
Accuracy of heights ±20 cm>

(2) Supplementary survey for 1:5,000 scale topographic map (Fig. 5)
Method of measurement
Azimuth by compass measurement
Distance and direction by stadia reading
Length of traverse route (branch route included) 57,090 metres
Number of traverse points 527
Area of supplementary survey about 9 square kilometres

(3) Establishment of grid points and measurement of heights (Table 7)
Number of grid points 84
Numberof heights measured 22

All the survey work has been based on the triangulation stations established by Survey of Pakistan and PMDC.

Table 6 shows the grid co-ordinates and heights of the drill holes executed during the present work.

Table 7-1 & 2 detail the same data of new grid points established by PMDC during the present work.

Tables 8-1, 2 & 3 show the grid co-ordinates and heights of drill holes executed by PMDC in 1976.

Table 6 LIST OF GRID CO-ORDINATES AND HEIGHTS OF DRILL HOLES EXECUTED BY PRESENT WORK (1979)

DRILL NO.	GRID CO-ORDINATES (m)		HEIGHTS (m)	DRILL NO.	GRID CO-ORDINATES (m)		HEIGHTS (m)
	Northing	Easting			Northing	Easting	
JT-1	902,726.	2,150,648.	126.130	JT-26	899,160.	2,153,455.	129.669
2	902,360.	2,151,035.	126.609	27	902,130.092	2,153,575.854	137.719
3	902,108.	2,150,634.	126.085	28	902,077.	2,154,274.	138.443
4	902,060	2,151,387.	127.280	29	901,419.	2,153,665.	134.330
5	901,136.937	2,150,632.172	124.280	30	900,946.	2,154,425.	133.395
6	901,105.	2,151,459.	124.207	31	900,294.	2,153,641.	130.801
7	900,970.	2,150,990.	123.520	32	899,264.	2,154,169.	133.284
8	900,380.	2,150,635.	121.680	33	902,682.986	2,154,138.491	141.530
9	900,550.	2,151,354.	123.155	34	902,430.	2,154,710.	138.046
10	899,465.	2,151,035.	119.400	35	902,615.	2,155,331.	137.150
11	899,021.938	2,150,631.860	119.250	36	901,872.244	2,155,207.876	136.435
12	900,797.146	2,152,410.749	125.634	37	899,770.187	2,150,692.836	121.260
13	902,779.410	2,152,278.400	134.800	38	901,140.	2,155,304.	128.087
14	902,340.	2,151,978.	131.521	39	900,898.858	2,154,890.607	124.324
15	901,965.	2,152,500.	133.530	40	900,323.	2,155,311.	135.238
16	901,684.	2,151,678.	126.514	41	899,792.	2,154,623.	135.954
17	901,113.	2,151,936.	125.448	42	899,720.	2,155,189.	127.217
18	900,547.	2,151,827.	123.552	43	902,662.	2,156,111.	141.116
19	900,137.	2,152,377.	123.888	44	902,153.	2,155,871.	139.571
20	899,769.	2,151,738.	123.400	45	901,489.	2,156,457.167	124.471
21	899,160.	2,151,972.	123.084	46	901,140.389	2,155,907.	116.882
22	902,625.516	2,153,252.075	135.540	47	899,856.	2,155,856.639	125.639
23	902,592.	2,152,854.	133.270	48	900,722.	2,156,604.	114.535
24	900,709.	2,153,156	133.380	49	900,098.	2,156,747.	112.092
25	899,750.	2,153,391.	131.322	50	899,180.	2,156,612	118.172

N.B. Co-ordinates and Heights of the drilling holes have been determined with reference to the triangulation stations established by PMDC based on the triangulation station of the Survey of Pakistan. (GRID 40 C/2)

Table 7 - 1 LIST OF GRID CO-ORDINATIONS AND HEISHTS

(by PMDC 1979)

GRID NO.	GRID CO-ORDINATES (m)		HEIGHTS (m)	GRID NO.	GRID CO-ORDINATES (m)		HEIGHTS (m)
	Northing	Easting			Northing	Easting	
1	904,500.	2,150,500.		31	903,000.	2,154,500.	140,341
2	904,000.	2,150,500.		32	902,000.	2,154,500.	137,665
3	903,000.	2,150,500.		33	901,000.	2,154,500.	134,266
4	902,000.	2,150,500.		34	900,000.	2,154,500.	135,830
5	901,000.	2,150,500.		35	899,000.	2,154,500.	135,479
6	900,000.	2,150,500.		36	904,500.	2,155,500.	130,109
7	899,000.	2,150,500.		37	904,000.	2,155,500.	146,450
8	904,500.	2,151,500.		38	903,000.	2,155,500.	
9	904,000.	2,151,500.		39	902,000.	2,155,500.	136,588
10	903,000.	2,151,500.		40	901,000.	2,155,500.	
11	902,000.	2,151,500.		41	900,000.	2,155,500.	138,324
12	901,000.	2,151,500.		42	899,000.	2,155,500.	121,000
13	900,000.	2,151,500.		43	904,500.	2,156,500.	
14	899,000.	2,151,500.		44	904,000.	2,156,500.	
15	904,500.	2,152,500.		45	903,000.	2,156,500.	
16	904,000.	2,152,500.		46	902,000.	2,156,500.	
17	903,000.	2,152,500.		47	901,000.	2,156,500.	
18	902,000.	2,152,500.	133,221	48	900,000.	2,156,500.	
19	901,000.	2,152,500.	128,594	49	899,000.	2,156,500.	
20	900,000.	2,152,500.	124,990	50	904,500.	2,157,500.	
21	899,000.	2,152,500.	125,088	51	904,000.	2,157,500.	
22	904,500.	2,153,500.	148,550	52	903,000.	2,157,500.	
23	904,000.	2,153,500.	149,000	53	902,000.	2,157,500.	
24	903,000.	2,153,500.	138,330	54	901,000.	2,157,500.	
25	902,000.	2,153,500	135,164	55	900,000.	2,157,500.	
26	901,000.	2,153,500.	134,575	56	899,000.	2,157,500.	
27	900,000.	2,153,500.	130,186	57	904,500.	2,158,500.	
28	899,000.	2,153,500.	129,612	58	904,000.	2,158,500.	
29	904,500.	2,154,500.		59	903,000.	2,158,500.	
30	904,000.	2,154,500.	144,000	60	902,000.	2,158,500.	

Table 7 - 2 LIST OF GRID CO-ORDINATIOSN AND HEIGHTS

(by PMDC 1979)

GRID NO.	GRID CO-ORDINATES (m)		HEIGHTS (m)	GRID NO.	GRID CO-ORDINATES (m)		HEIGHTS (m)
	Northing	Easting			Northing	Easting	
61	901,000.	2,158,500.					
62	900,000.	2,158,500.					
63	899,000.	2,158,500.					
64	904,500.	2,159,500.					
65	904,000.	2,159,500.					
66	903,000.	2,159,500.					
67	902,000.	2,159,500.					
68	901,000.	2,159,500.					
69	900,000.	2,159,500.					
70	899,000.	2,159,500.					
71	904,500.	2,160,500.					
72	904,000.	2,160,500.					
73	903,000.	2,160,500.					
74	902,000.	2,160,500.					
75	901,000.	2,160,500.					
76	900,000.	2,160,500.					
77	899,000.	2,160,500.					
78	904,500.	2,161,000.					
79	904,000.	2,161,000.					
80	903,000.	2,161,000.					
81	902,000.	2,161,000.					
82	901,000.	2,161,000.					
83	900,000.	2,161,000.					
84	899,000.	2,161,000.					

Table 8-1 LIST OF GRID CO-ORDINATIONS AND HEIGHTS

(by PMDC 1976)

TRIANGULATION STATION/POINT	GRID CO-ORDINATES (Metres)		HEIGHTS (Metres)
	Northing	Easting	
Wen	897,108.696	2,157,362.208	165.594
4	897,549.007	2,156,215.911	131.670
3	897,849.396	2,154,999.036	135.501
6	898,512.273	2,155,359.935	128.929
2	898,708.887	2,154,626.226	138.029
A	898,187.014	2,154,110.195	133.663
B	899,140.625	2,154,107.328	133.917
1	898,513.597	2,153,033.594	130.796
b	899,905.378	2,153,896.546	133.898
c	900,427.000	2,153,995.053	134.582
d	900,217.947	2,154,677.931	137.644
e	901,399.505	2,153,955.293	137.710
f	901,017.119	2,154,582.525	140.480
g	901,701.844	2,155,453.954	138.645
h	902,003.983	2,154,470.754	142.426
i	902,768.752	2,155,527.215	145.505
j	904,027.882	2,155,452.224	148.206
k	903,454.957	2,156,419.929	147.133
l	904,294.035	2,156,106.898	-
m	903,899.458	2,157,464.214	143.866
n	903,043.843	2,157,297.829	147.130
o	901,977.183	2,156,664.408	145.860
p	903,887.869	2,159,458.404	131.560
q	902,849.170	2,158,410.140	142.400
r	903,844.415	2,158,342.865	126.720
S	903,039.463	2,159,316.932	132.260
T (427)	904,172.291	2,160,004.968	130.149
(491)	904,839.229	2,157,588.678	149.656
A'	902,971.069	2,153,951.408	142.044
B'	903,492.309	2,154,597.083	144.658
5	896,627.631	2,156,787.205	132.315
a	897,581.932	2,157,373.952	161.950
7	898,388.800	2,157,494.221	141.134
(490)	899,657.470	2,157,229.700	149.352
9	900,244.087	2,158,371.476	153.620

Table 8-2

TRIANGULATION STATION/POINT	GRID CO-ORDINATES (Metres)		HEIGHTS (Metres)
	Northing	Easting	
10	899,467.744	2,158,711.832	154.503
12	900,684.764	2,159,159.070	153.000
13	900,218.169	2,159,470.316	152.400
(526)	899,796.846	2,159,987.993	160.325
(475)	901,560.701	2,159,282.113	144.780
(495)	900,745.557	2,160,136.023	150.876
15	900,187.837	2,161,161.384	140.680
16	901,154.821	2,161,668.967	129.240
17	901,122.622	2,160,739.420	136.688
18	901,629.086	2,160,228.868	131.340
19	901,945.577	2,159,604.503	135.550
20	901,823.706	2,161,072.793	126.660
22	902,114.518	2,160,274.455	121.670
(440)	902,785.906	2,161,634.005	134.112
21	903,889.979	2,161,094.648	123.670
(420)	903,157.890	2,160,436.051	128.016
U	903,482.309	2,159,989.885	132.570
8	899,528.700	2,154,702.800	139.898
A 1	900,663.646	2,152,641.978	136.680
A 2	898,775.750	2,152,431.946	128.860
A 3	900,326.222	2,151,208.766	124.190
A 4	901,908.291	2,151,847.030	134.890
A 5	900,882.060	2,150,656.115	126.120
A 6	899,248.143	2,150,972.612	122.170
A 7	899,262.843	2,150,054.995	122.120
A 8	901,730.091	2,150,695.594	126.810
A 9	902,638.872	2,150,733.159	126.740
A10	902,846.587	2,151,622.317	136.420
A11	902,350.811	2,152,572.902	137.500
A12	904,078.752	2,150,691.644	124.460
A13	904,354.462	2,151,615.330	133.380
A15	901,947.561	2,153,205.257	137.980
A16	903,110.103	2,153,324.699	143.770
A18 (506)	904,016.104	2,153,619.053	154.230
A19	904,646.947	2,152,796.503	144.400
W 1	901,142.024	2,157,378.035	142.958
W 2	899,276.049	2,155,700.973	122.106
W 3	904,398.406	2,154,821.403	-
W 4 (520)	905,487.899	2,154,053.391	158.496
W 5	899,975.962	2,155,856.639	138.990

Table 8-3

TRIANGULATION STATION/POINT	GRID CO-ORDINATES (Metres) Northing	Easting	HEIGHTS (Metres)
H 6	901,354.047	2,156,457.167	148.909
H 7	901,941.759	2,158,682.664	142.648
H 8	901,280.717	2,158,720.945	144.782
H 9	900,646.442	2,155,687.776	139.385
PS 1	899,258.045	2,155,705.276	120.180
PS 2	899,388.036	2,158,558.279	126.880
PS 4	900,681.860	2,158,862.462	115.330
PS 5	900,412.051	2,156,140.753	116.630
PS 6	901,334.680	2,152,755.969	134.350
PS 7	901,563.486	2,154,429.587	134.920
PS 8	901,597.947	2,155,746.848	132.860
PS 9	902,653.661	2,158,459.713	139.780
PS10	901,250.029	2,160,212.611	107.070
PS11	903,099.094	2,159,755.224	116.790
PS13	903,227.902	2,156,579.241	143.150
PS14	903,155.588	2,155,011.258	142.170
PS15	903,809.788	2,154,315.326	143.490
PS18	899,334.511	2,152,769.418	126.900
PS19	899,960.272	2,151,102.502	121.340
PS20	901,636.141	2,151,037.709	125.880
PS22	903,107.379	2,151,083.248	127.160
PS23	903,071.786	2,152,837.461	138.110
PS24	904,031.920	2,151,930.218	132.800
P 12	903,159.992	2,158,147.077	-
P 16	903,882.332	2,157,232.854	-
P 21	901,846.948	2,152,193.639	-
L 18	900,024.168	2,157,326.622	117.040
L 22	901,707.167	2,157,427.293	115.600
L 28	900,090.222	2,154,115.879	133.670

N.B. PS = denotes drill holes executed by PMOC

L = denotes drill holes executed by GSP

P = proposed drill holes by PMOC

CHAPTER 3 GENERAL GEOLOGY

3-1 General Description of Geology of Lakhra Coal Field (After PMDC, 1976)

The formations exposed in Lakhra coal field are detiled in Table 9.

Ranikot group, the oldest exposed rocks, crops out in the southern part of Lakhra coal field. It underlies Laki limestone unconformably in the northern, eastern and western parts. Manchar formation unconformably overlies Ranikot and Laki groups in the western area of the central part of the field.

The strata constitute a doubly plunging anticline, popularly known as Lakhra dome axis of which runs in north-south direction. They generally dip gently towards all sides. The dips are low and do not exceed 7°. The coal field is located along the crestal part of the anticline and the seams are almost horizontal. It is affected by about 46 faults, which generally trend north-south, and are high angle faults with dips ranging from 52° to near vertical. Invariably all are normal faults and their throws do not exceed 43 metres.

Upper part of Lower Ranikot formation is coal bearing. It contains at least 10 seams as per data collected through drilling. Lailian is by far the most important seam, which has been encountered in most of the executed holes and in underground mines to the south of PMDC's block. Its depth from the surface ranges from 20 to 60 metres. Besides Lailian, two locally mineable coal seams – Dhanwari above and Kath below the Lailian -- also exist in the area.

3-2 Summarized Description of the Geology of Investigated Area

The investigated area occupies about 26 square kilometres on the western side of the block of PMDC's licences measuring 52 square kilometres. Save southeastern corner and some valleys in the centre of the block, where Upper Ranikot formation is exposed, the remaining 80 percent of the area is underlain by Laki limestone. Consequently there is no exposure of coal seams.

In the present work, 50 drill holes have been executed, and subsurface geological conditions and coal seams have been investigated together with the data collected through 19 holes by PMDC and 3 holes by GSP drilled in the area previously. Based on the results of investigations, the 'standard stratigraphic succession' detailed in Table 2 has been prepared.

Logging of cores could not reveal relationship between Laki and Ranikot groups, because of non-core drilling through Laki limestone for the sake of drilling efficiency.

Investigated part of Ranikot group has been divided into four members on the basis of occurrence of fossil shells and coal seams. The members are Upper Shell Beds, Upper Coal-bearing Beds, Lower Shell Beds, and Lower Coal-bearing Beds.

Upper Shell Beds consist predominantly of sandstones interbedded with siltstones, and contain abundant fossil shells. Siltstones at many places bear siderite or sandy nodules. The Beds correspond to the Upper Ranikot formation reported by PMDC.

The Beds are variegated and display red, brick red, violet, brown, yellowish brown, white, etc. colours in almost all the drill holes except JT1, JT2 and JT32. This red zone extends

Table 9.

STRATIGRAPHIC SUCCESSION IN LAKHRA AREA

Era	Period	Epock	Group	Formaiton	Unit	Lithology
	Quaternary	Recent & Sub-Recent		Recent & Sub-Recent Deposits.		Unconsolidated surficial deposits of silt, sand, clay and gravel.
	Quaternary	Recent & Sub-Recent		Recent & Sub-Recent Deposits.		Consolidated deposits of unsorted pebbles and cobbles of Laki limestone and other formations
						Unconformity
CENOZOIC	Tertiary	Pliocene		Manchar		Alternations of sand-stones, shales and siltstones with clay and thin grit beds. Fossiliferous. Contains petrified wood mostly.
						Unconformity
CENOZOIC	Tertiary	Eocene	Laki	Laki Limestone		Limestones with sub-ordinate shales and marls.
CENOZOIC	Tertiary	Eocene	Laki	Basal Laki Laterite		Intermingled lateritic clays, sandstones and gypsiferous shales with sub-ordinate pockets of sand. Unfossiliferous. 1.5 metres to 14 metres thick.
						Unconformity
CENOZOIC	Tertiary	Paleocene	Ranikot		5	Limestone with sub-ordinate shales. Fossiliferous. 39 metres to 46 metres thick.
CENOZOIC	Tertiary	Paleocene	Ranikot		4	Sandstones with minor shales. Fossiliferous. 14 to 15 metres thick.
CENOZOIC	Tertiary	Paleocene	Ranikot		3	Interbedded limestones and shales. Fossiliferous. 13 metres to 23 metres thick.
CENOZOIC	Tertiary	Paleocene	Ranikot		2	Shales with thin beds of sandy limestone. Fossiliferous. 17 to 24 metres thick.
CENOZOIC	Tertiary	Paleocene	Ranikot		1 C	Sandstones and shales interbedded. Fossiliferous. 7 metres to 8.5 metres thick.
CENOZOIC	Tertiary	Paleocene	Ranikot		1 B	Shales with sandstone bed. Fossiliferous. 6 metres to 7.5 metres thick.
CENOZOIC	Tertiary	Paleocene	Ranikot		1 A	Sandstones and shales interbedded. Fossiliferous. 21 metres to 23 metres thick.
CENOZOIC	Tertiary	Paleocene	Ranikot	Lower Ranikot		Predominant sandstones interbedded with shales, claystones and siltstones. Mostly unfossiliferous. Impregnated with 10 coal seams of which Lailian and the one below it are workable. A light grey to grey clay bed upto 3 metres thick above the Lailian seam may prove to be refractory grade fire-clay.

- Base not seen -

occasionally to the top of the Upper Coal-bearing Beds, and in some cases penetrates through it reaching the Lower Shell Beds.

During the course of investigations a new coal horizon has been found. Therefore, the Lower Ranikot formation has been divided into three members mentioned above.

The Upper Coal-bearing Beds are 20 to 56 metres thick. They are impregnated with 11 coal seams falling in 5 coal zones, which in ascending order are – No. 1, No. 2, No. 3, No. 4 and No. 5. Coal zones No. 1 and No. 2 merge in the eastern part of the area. No. 1, No. 2 and No. 3 zones are fairly persistent, whereas No. 4 and No. 5 zones become thinner towards east. The persistent zones correspond to Dhanwari, Lailian and Kath seams reported by PMDC. Though exact correlation is difficult, it appears more likely that No. 1 coal zone corresponds to Lailian or Kath, No. 2 to Lialian or Dhanwari, No. 3 to Lailian or Dhanwari, and No. 4 to Dhanwari.

Drill-holes JT6, JT11, JT12, JT13, JT17, JT18, JT20 and JT22 in which red zone extends to a considerable depth are either barren or poor in coal, and the coal horizons are represented by scattered coaly matter. Therefore, two barren areas, one near the southwestern corner and the other in the northern part of the investigated area have been delineated.

The Lower Shell Beds underlie Upper Coal-bearing Beds. They consist of predominant sandstones and are rich in fossil shells. The thickness has been noted from 20 to 40 metres.

Lower Coal-bearing Beds lie below the Lower Shell Beds. They contain coal seams as encountered in drill holes JT28, JT33, JT37, JT39, JT45, JT49 and JT50. Encouraged by this the Beds were examined carefully and their existence has been confirmed in 20 drill-holes. However, their bottom could not be fixed due to insufficient data. Consequently, the thickness and coal potential of the Beds is uncertain so far. The Beds are 30 metres or more in thickness. They contain three coal zones, which is descending order are – L1, L2 and L3. As the seams are generally thin, less than 0.92 metre, and number of holes penetrating the Beds are few, the continuity of seams could not be established and the coal potential of the Beds has not been estimateed.

The Beds and coal seam dip at about 2°. Axis of Lakhra anticline is expected to run along eastern margin of the area. However, due to almost horizontal disposition of strata it is not distinct even in the geologic sections. In the central part of the area near southern boundary there are faults between drill-holes PS18 and JT26, and JT32 and PS1. The former named as fault A down-throws about 25 metres to the east and trends north to northwest. The latter referred as fault B1 trends north-south. Its maximum throw is 30 metres displacing western side downwards. Third fault B2 branches out from fault B1 between the holes JT41 and JT42. It trends northeast and has a throw of 15 metres to the west. All the faults are pivotal. Their throws decrease northwards and they die out in the investigated area.

The investigated area is divided into three blocks based on these faults, and the barren areas described above. To the west of fault A is western block, area between faults A and B1 is named as central block, and to the east of fault B1 is eastern block.

Coal seams in the Upper Coal-bearing Beds have been evaluated. Reserves have been calculated separately for mining by open-cut and underground methods. As strip ratio is the most important factor for open-cut mining, the coal reserves based on strip ratios under 1:10, 1:12, 1:15, 1:17 and 1:20 have been estimated for coal seam above 0.50 metre thick. For underground mining, roof and floor conditions and thickness of the seams are important factors. Therefore coal seams with unfavourable roof or floor conditions have not been considered as reserve. Seams with favourable mining conditions have been evaluated for thickness from 0.50 to 3.50 metres at an interval of 0.50 metre (for detailed description please see Chapter 5). The estimated reserves are summarized in the Table 3.

As apparent from the Table, the reserves in the central and eastern blocks have been calculated both for open-cut underground mining because both the methods appear to be possible in the blocks.

Depth of coal seams in southern part of the central block is considerable, and the strip ratio over a part of the area is more than 1:17. Open-cut mining in this part would not be possible from economic point of view. This part will therefore be left for underground mining in case the block would be mined by open-cut method.

The Table shows that by underground method coal in entire central block would be mined, but by open-cut method, the southern part would remain for underground mining.

Whether open-cut or underground mining would be more economical and practical will be determined by the mining feasibility study.

Each coal seam in the investigated area seems to be lignite A and rarely sub-bituminous C in rank. Their moisture content appears to be considerably high, but when open to air the coal lumps lose moisture and crumble. On air dried basis the moisture content is determined to range from 5.5 to 14 percent, and calorific value from 3,500 to 5,860 kcal/kg. The seams are impregnated with pyrite, marcasite and gypsum veins, and total sulphur content is from 3.3 to 18.1 percent.

It has been known empirically that the coal is liable to spontaneous combustion. Tests for spontaneous combustibility confirm the same.

3-3 Detailed Geologic Description

As already mentioned the investigated area occupies western part of the block of PMDC licences. The area is overlain by the following:-

Recent deposits	Quaternary
Manchar formation, Pliocene	Tertiary
Laki group, Eocene,	Tertiary
Ranikot group, Paleocene,	Tertiary

Coal measure belongs to Ranikog group and no seam is exposed on the surface. As the object of investigation was to evaluate coal, which belongs to Ranikot group, the Laki group not important for the purpose has been drilled almost non-coring. Consequently, only few drill holes (JT1, JT3, JT15, JT28, etc.) were directed coring through Laki to check the unconformable relationship between the Laki and Ranikot groups.

Manchar formation and Quaternary deposits are beyond the scope of present investigations.

3-3-1 Ranikot Group

Based on the data collected through 50 drill holes, the Ranikot group is divided into four members, which in descending order are Upper Shell Beds, Upper Coal-bearing Beds, Lower shell Beds and Lower Coal-bearing Beds.

The group outcrops from central part of the PMDC's block along the upper reaches of Kath Butthi stream and is exposed towards south over about half of the area of Lakhra coal field. As the nature of work required emphasis on drilling, study of cores and analysis of data thereof, the mode of occurrence of above said members has not been examined on surface. Further, the relationship between these four members and Upper and Lower Ranikot formations as well as the sub-divisions of Upper Ranikot formation by PMDC have not been subjected to detailed study. However, the Upper Shell Beds correspond to Upper Ranikot formation and other three members belong to Lower Ranikot formations as correlated roughly on the basis of lithology. The Lower Coal-bearing Beds have been established during the present work, and it appears that the coal seams encountered in drill-hole PS-15 belong to these Beds.

The Ranikot group has unconformable contact with Laki group. Mostly, it underlies Basal Laki laterite, but at places it is in direct contact with the Laki limestone. The group is reported to be more than 305 metres thick, and study of its base is beyond the scope of the present work. Strata in the upper part of the group change into variegated lithologic facies upto a considerable depth. The variegated colours resemble the shades exhibited by Basal Laki laterite and make it difficult to distinguish between the two. Whether the variegated colours are due to primary sub-aerial weathering, secondary migration of acidic water or deposition of quite different facies as on surface of weathering could not be ascertaining because of the lack of detailed data.

Rocks of the group whether sandstones or siltstones are rarely composed of homogeneous lithology and grain size. Sandstones contain varying amounts of argillaceous material. Similarly, siltstones and claystones include lot of sand grains. So called silica sandstone is one of the exceptions as it consists mainly of quartz grains loose and unbonded to the extent that its core recovery was nil to very poor. Second is claystone called refractory clay in the field. This rock too has a fairly homogeneous appearance. Gypsum veins occur in almost all the strata. Besides, siderite, sandy nodules and sometimes glauconite occur in the Upper and Lower Shell Beds. Fossil shells are abundant, but broken mostly and complete ones are sporadic.

Host rocks of coal seams are usually rich in carbonaceous matter. Occasionally, the strata at considerable intervals from the coal seams are also rich in carbonaceous matter. When traced laterally such strata in some cases transform into coal seams.

Fresh rock samples of the group are commonly pale grey to dark grey, and brownish black due to carbonaceous matter. Sometimes they are greyish white. Glauconite bearing rock is greenish. So called refractory claystone is pale blue immediately after coring.

(1) Lower Coal-bearing Beds

The Beds were noticed to bear coal seams during the course of drilling. Therefore, from the beginning of October, drilling was directed to penetrate these Beds as far as possible. However, the depths of holes drilled before October were insufficient to probe them, and their existence throughout the area could not be confirmed. Though the seams in the Beds are thin, their correlation is comparatively easy as compared to the seams in the Upper Coal-bearing Beds. It indicates that the depositional environment of the Lower Coal-bearing Beds is more stable, and it is highly probable that they spread over entire investigated area. Bottom of the Beds could not be confirmed, because of their depths. However, it appears that there may be more coal seams with appreciable thickness in the areas where the Beds would be thickest.

The Beds appear to be 30 metres or more in thickness. They contain at least three coal zones referred as L1, L2 and L3 in descending order. Each zone bears one to four coal seams (see Chapter 5 for detailed description of coal seams). Top of the Beds has been fixed at roof of zone L1 for the sake of convenience. Zone L1 ranges from trace to 2 metres, L2 from trace to 4 metres, and L3 from trace to 5 metres in thickness, whereas the strata between L1 and L2 are 5 to 20 metres, and those between L2 and L3 are 5 to 23 metres thick.

The Beds are composed of predominant sandstones alternating with sub-ordinate siltstones, shales, claystones and coal seams. Sandstones are light grey mostly and brownish, yellowish, and greyish white, etc. They are fine to medium and sometimes very fine grained. Except loose sand, they are medium hard. Laminations and lenses of silt and carbonaceous matter are frequent at places. Siltstones and shales are grey to dark grey generally, and contain laminations and lenses of sand, carbonaceous matter and sandstone nodules. Claystones are pale bluish grey with sporadic black spots. Host rocks of and partings in the coal seams are mainly composed of shales and claystone.

Sandstones and siltstones between zones L1 and L2 bear fossil shells and occasional sandstone nodules. Fossil shells are rare and loose sand abundant between zones L2 and L3. Loose sand between L1 and L2 occurs only at places.

(2) Lower Shell Beds

The Beds overlie the Lower Coal-bearing Beds conformably. From its bottom along the roof of L1 to the top fixed at base of zone No. 1, they are from 20 to 40 metres thick. They consist of alternating beds of sandstones and siltstones with rare shales and thin coal seams. At places the sandstones are predominant.

Sandstones are greyish white to grey, sometimes light brown or brownish yellow; fine to medium and at places very fine grained, hard and compact to loose and soft. Laminations and lenses of silt, carbonaceous matter, fossil shells, glauconite grains, sideritic nodules and at places pebbles are present.

Silstones are grey to dark grey, mostly sandy, contain laminations and lenses of sand/sandstone and, carbonaceous matter, fossil shells, pyrite and rarely glauconite grains. Upper part of the Beds, particularly along the base of zone No. 1 are composed of loose sand/soft and uncompact sandstone or siltstone bearing sideritic nodules and fossil shells.

(3) Upper Coal-bearing Beds

They overlie the Lower Shell Beds conformably, and bear the most important coal seams in the investigated area. Eleven coal seams including thin and insignificant ones have been located in the Beds. They have been divided into five zones designated as No. 1, No. 2, No. 3, No. 4

and No. 5 zones in ascending order based on the pattern of distribution of coal seams, lithology between the seams, etc. Top of the Beds is placed in the roof of zone No. 5 or its equivalent.

Thickness of zone No. 1 ranges from 0.2 to 7.0 metres, No. 2 from 0.1 to 8.0 metres, No. 3 from 0.05 to 4.5 metres, No. 4 from trace to 2 metres and No. 5 from trace to 1.2 metres. Lithologic units between No. 1 and No. 2 zones are zero to 13.5 metres, No. 2 and No. 3 are 1 to 21 metres, No. 3 and No. 4 are 1 to 10 metres, and No. 4 to No. 5 are 3 to 27 metres thick. Thus the total thickness of Upper Coal-bearing Beds is from 20 to 56 metres (see Chapter 5 for detailed description of coal seams).

The investigated area is characterized by frequent facies changes. The coal zones are no exception and show lateral variations. Pattern of the zones in the western part is fairly different from that in the eastern part. Also there are no key beds. These factors make correlation of seams very difficult. However, correlation has been attempted on the basis of coal zone No. 1, which is the first coal horizon after the relatively stable environment of deposition of Lower Shell Beds and Lower Coal-bearing Beds.

Coal zones No. 1, No. 2 and No. 3 appear to be fairly persistent though their thicknesses vary considerably. No. 4 and No. 5 zones are developed at places, and in some holes their traces only have been found. No. 1 and No. 2 zones are distinct in the western part, but they merge as one zone in the eastern part.

As mentioned already, the Upper Coal-bearing Beds are the main coal measure in the investigated area. However, in the area enclosing drill holes JT6, JT11, JT12, JT17, JT18 and JT20, and the area with drill holes JT13, JT22 and PS15, the Beds are either barren or contain very thin and insignificant coal. Only carbonaceous matter in the horizons corresponding to the zones suggest the trace of environment of coal deposition.

The Upper Coal-bearing Beds consist of alternating sandstones and siltstones intercalated with shales, coal seams and claystones. Sandstones are light grey to grey, at places greyish white and dark grey, hard and compact to loose and soft. They contain laminations and lenses of silt, carbonaceous matter, pyrite and resins. Strata between No. 1 and No. 3 zones consist of sand and soft sandstones in the eastern part. Siltstones are grey to dark grey and greyish brown, sandy with laminations and lenses of sand, carbonaceous, pyritic and micaceous. Siltstones between No. 4 and No. 5 zones contain siderite nodules and fossil shells in the western part. Shales are dark grey to black. They are sandy at places and, contain pyrite and marcasite. They become rich in carbonaceous matter near the contact with coal seams. Claystones pale grey to light bluish grey with sparse black spots have been named as refractory clay in the field. They mostly enclose coal seams in the zones and are rich in carbonaceous matter. Siltstones predominate the Beds in western part and grade into sandy facies towards east where they are subordinate to sandstones.

(4) Upper Shell Beds

They extend from roof of zone No. 5 upto Basal Laki laterite, and Laki limestone where the laterite is missing. Thickness of the Beds is affected by unconformity between Ranikot and Laki groups. It ranges from 9 to 70 metres plus. In general the thickness decreases from east to west.

The Beds are composed mainly of sandstones, intercalated siltstones and rarely claystones. In general the lower part is dominated by sandstones and the upper part by siltstones. At places, however, the siltstones dominate the entire column. In few cases conglomerate and/or limestone with calcareous and/or silty gravel were encountered along the top of the Beds. Sandstones are variegated, greyish white to grey and dark grey with brownish and yellowish shades. They are medium to fine grained mostly, hard and compact to soft and loose. At places they are silty and, contain laminations and lenses of silt. Carbonaceous matter, resins, fossil shells, glauconite grains and pyrite are present.

Siltstones are grey to dark grey, sandy, laminations and lenses of sand are present at places, carbonaceous and pyritic. They give typical appearance when siderite nodules and fossil shells are present. The Beds are rich in fossil shells.

(5) Red Zone

As mentioned above, the upper part, and at places entire Upper Shell Beds and Upper Coal-bearing Beds exhibit characteristic variegated colours mostly of different reddish shades. All lithologic facies sandstones, siltstones, shales and claystones display colours including red, brick red, reddish brown, violet, white, yellowish white, pale yellowish white, yellow, yellowish brown, brownish red, etc. Rocks with yellow to white colour are comparatively soft, while the reddish rocks are hard. It is difficult to distinguish these variegated rocks from Basal Laki laterite, as it consists of lithologic units with similar characteristics. Some sandstones present slag-like appearance and produce metallic sound on hammering. Another typical sandstone has cavities developed probably due to the erosion of fossils or soft inclusions. There is no coal seam and only carbonaceous matter or oxidized coaly shale are found in this red zone.

The red zone is absent in drill holes JT1, JT2 and JT32, and there the Upper Shell Beds are directly in contact with Laki limestone. It could not be confirmed in drill holes JT26, JT47 and JT50, because there the drilling was conducted non-coring above the coal zones. Depth of the zone fluctuates very much, and it extends downwards even upto the Lower Shell Beds. Besides, it appears to split, and is repeated in some drill-holes after coring through normal strata with usual colours. Its boundaries do not follow the bedding surfaces. They are mostly distinct, but become gradational when the lithology enclosing them consist of siltstones or claystones. The zone contains plant fragments and carbonaceous matter. Gypsum veins from 1 to 5 cm thick are frequent and the fossil shells occur rarely.

Red colour appears to be imparted by hematite and yellow of brownish yellow by iron hydroxide. Concerning the origin of the zone, detailed studies are necessary. However, besides a secondary change, an unconformity between the zone taken as primary and the normal rock facies can be considered.

3-3-2 Basal Laki Laterite

It is exposed mostly along the base of steep scarps of eroded Laki limestone and rests on Upper Ranikot formation unconformably. It is absent in some areas, and Upper Ranikot formation has been found to underlie Laki limestone directly.

Basal Laki laterite comprises of intermingled lateritic clays, sandstones and gypsiferous shales with subordinate pockets of sand. Clays are violet to reddish brown, sandy and highly ferruginous. Sandstones are yellowish brown and light to dark grey, fine to medium grained with rounded to sub-rounded grains. Mostly they are thin to medium bedded. Cross-bedding is present. The sandstones are loosely compact to hard, and ferruginous. Shales are variegated, laminated, crumbly, loose and soft. They contain frequent gypsum veins and considerable ferruginous materials. Sand is fine to medium grained with rounded to subrounded and sorted grains. It is massive with occasional intercalations of thin, dark brown, ferruginous clay layers. It is upto 14 metres in thickness in Lakhra area.

3-3-3 Laki Limestone

Laki limestone extends over about 80 percent of the investigated area, where its thickness has been noted upto 54 metres. Out of 50 executed drill holes, 10 holes (JT12, 18, 38, 39, 42, 45, 47, 48, 49 and 50) are located on Upper Ranikot formation exposed in the valleys of Kath Butthi stream and its tributaries, and in 4 drill holes (JT11, 14, 19 and 27) limestone could not be confirmed, whereas in the remaining 36 drill holes Laki limestone has been confirmed by drilling core and sludge. Limestone thickness varies from hole to hole. Generally, it is more thick to the north, west and in southern half of the central part of the investigated area. Its average thickness as noted in 36 drill holes is 20 metres approximately.

The formation consists of limestones with subordinate shales and marls. The limestones are white, milky white, pale yellow, pale grey in fresh, and cream, yellow, yellowish white, pale yellow on weathered surfaces. They are thin bedded to massive and rubby to nodular. They are hard and compact. At places they are chalky and cherty. Marine fossils with predominant foraminifera are present in abundance. Shales are khaky to earthy, gypsiferous, calcareous and marly. Marl is yellowish brown, dirty white and buff, soft and loosely compact. It is argillaceous and intercalated with thin beds of nodular limestones. White to yellow clay is present along some fracture surfaces. Laki limestone has an extensive distribution. It occurs in and around Lakhra coal field, and extends to Hyderabad city. It rests on Basal Laki laterite conformably, but where the laterite is absent, it directly overlies the Ranikot formation.

3-3-4 Manchar Formation

The Manchar formation has an extensive distribution to the west and south-west of PMDC's block and in the northern part of Lakhra coal field. In the investigated area, its small and thin outliers only are scattered in the western part. The formation consists of sandstones, shales and siltstones with clay and thin grit beds. It overlies the Laki limestone and Ranikot formations unconformably. It is fossiliferous and contains petrified wood. The sandstones are yellow to dark brown, fine to coarse grained with rounded sub-rounded and poorly sorted grains. They contain considerable argillaceous and ferruginous materials. They are thick bedded with cross-bedding, hard to soft and friable. Shales are greenish grey with reddish bands, sandy and ferruginous. Siltstones, yellow to greenish grey, are loosely compact. A thin grit bed, brown, hard and compact, containing unsorted pebbles of Laki limestones in arenaceous and argillaceous matrix occurs at base of the formation.

3-3-5 Quaternary Deposits

The deposits, very few and limited in the investigated area, consist of talus and thin soil layers in the depressions and along valley floors. Along river Indus to the east, the fluviatile quaternary deposits are distributed extensively.

3.4 Geologic Structure

3-4-1 General Geologic Structure of Lakhra Coal Field

Lakhra area consists of a doubly plunging anticline, which has been eroded along the crestal part exposing the strata upto upper part of Lower Ranikot formation and the unconformity between Upper Ranikot formation and Laki group. The anticline axis runs almost north-south. It plunges under Manchar formation just north of the field. Folding is very gentle and the strata dip at low angles upto 7° towards all the sides. Dips in the crestal part average upto 2° only making it very difficult to determine axis on the cross-sections. The area is marked with almost north-south trending 46 faults, which occur frequently near the apex. They are high angle normal faults with dips varying from 52° to near vertical. Quite a few faults are pivotal.

3-4-2 Geologic Structure of the Investigated Area

The investigated area spreads over the western side of the block of PMDC's licences, and the anticline axis runs along its eastern margin. It is faulted and bears outcrops of unconformable contacts as discussed below.

(1) Fold

Lakhra anticline is a very gentle fold as mentioned above. The strata dip at very low angles with an average of 2 degrees. They are rolled and near the borders of barren areas the rolls develop remarkably. Some parts of the rolls may be due to faulting.

(2) Faults

In the present work, no big fault capable of controlling the geologic structure of the area has been encountered in the drilling.

Three faults have been inferred based on the difference in depths or dislocation of some coal seams in adjacent drill holes. Dips of the faults have been presumed at 60° as they could not be confirmed during the course of work. Fault in the western part of the area has been referred as fault A. It runs between drill holes PS19-JT25, JT12-JT24, JT19-PS6, JT16-JT15 and JT4-JT14. Second fault named as fault B1 lies to the east of fault A. It is located between drill holes JT32-PS1, JT41-JT42 and JT30-JT39. Third one, fault B2 branches out from fault B1 at a point between drill holes JT41-JT42, and runs between JT40-PS5, and JT38-JT46.

Fault A is normal and pivotal. It dips toward east. Its throw has been measured at 25 metres between PS18-JT25, about 10 metres between JT17-PS6, and nil between JT4-JT14. Fault B1 is also normal and pivotal. It dips towards west. Its throw is about 30 metres between JT32-PS1. The throw decreases suddenly between JT40-JT41 from where fault B2 branches out and is nil between JT30-JT39. Fault B2 like the other two is normal and pivotal. It dips west, and the throw is about 15 metres between JT40-PS5, and nil between JT38-JT46.

As the structural disturbances pose serious problems in underground mining, it becomes very important to decipher the geologic structure with full understanding as to whether the differences in depth of coal seams are due to faulting or folding. More detailed exploration through drilling will be necessary to delineate and understand the structure fully.

(3) Unconformity

Core drilling from Laki limestone to Upper Coal-bearing Beds has been carried out at sites JT1, JT2, JT3, JT5, JT15, JT22, JT23, JT24, JT28 and JT44. It has been found that the Basal Laki laterite is missing in drill holes JT1 and JT2, and Upper Shell Beds without 'red zone' are in contact with Laki limestone. The Upper Shell Beds, which lie between Upper Coal-bearing Beds and Laki group are less than 10 metres thick in the drill holes JT1 and JT2, about 70 metres thick in PS11, and between 10 to 70 metres in other holes. This suggests an unconformity between Ranikot and Laki groups.

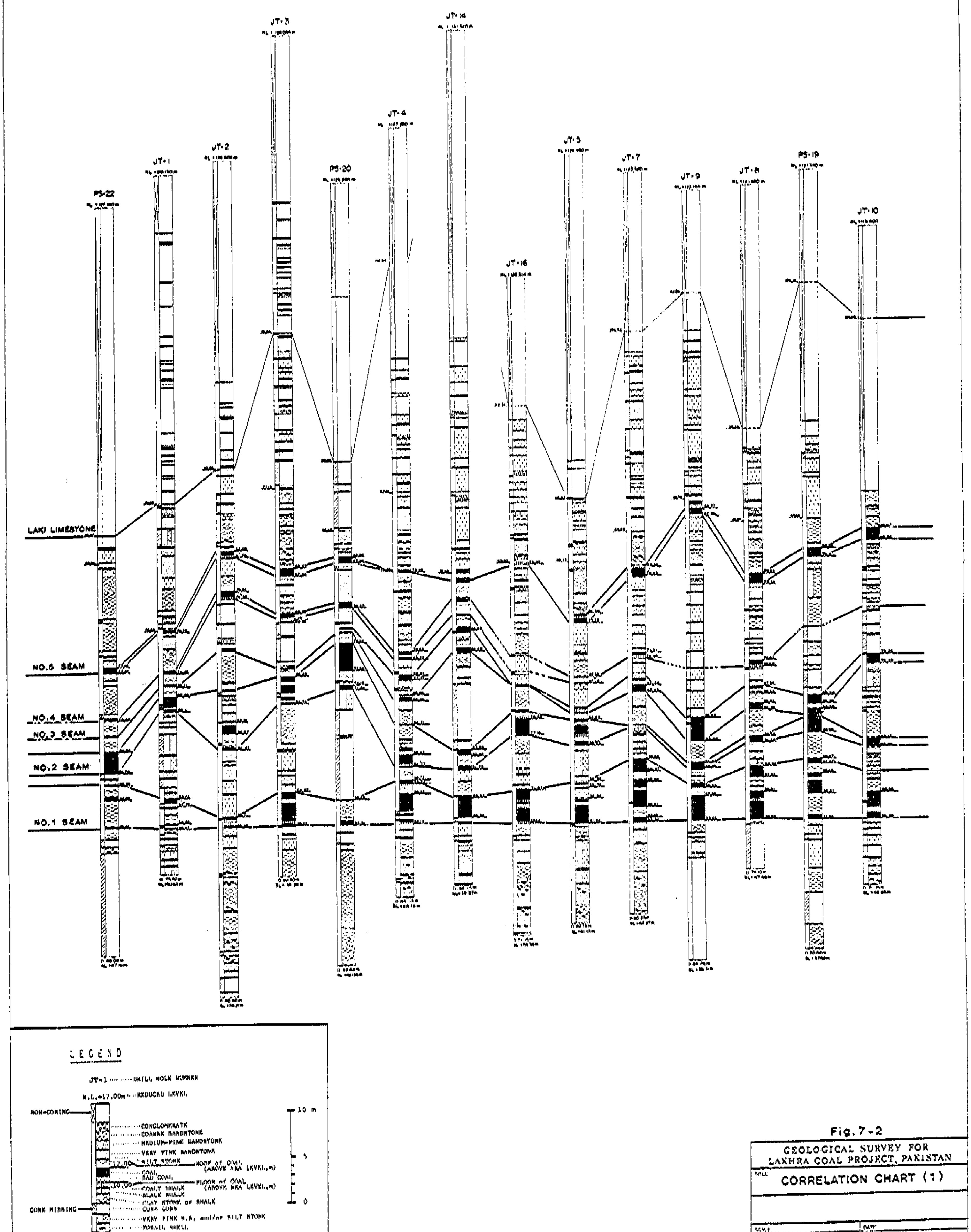


Fig. 7-2

GEOLOGICAL SURVEY FOR LAKHRA COAL PROJECT, PAKISTAN

CORRELATION CHART (1)

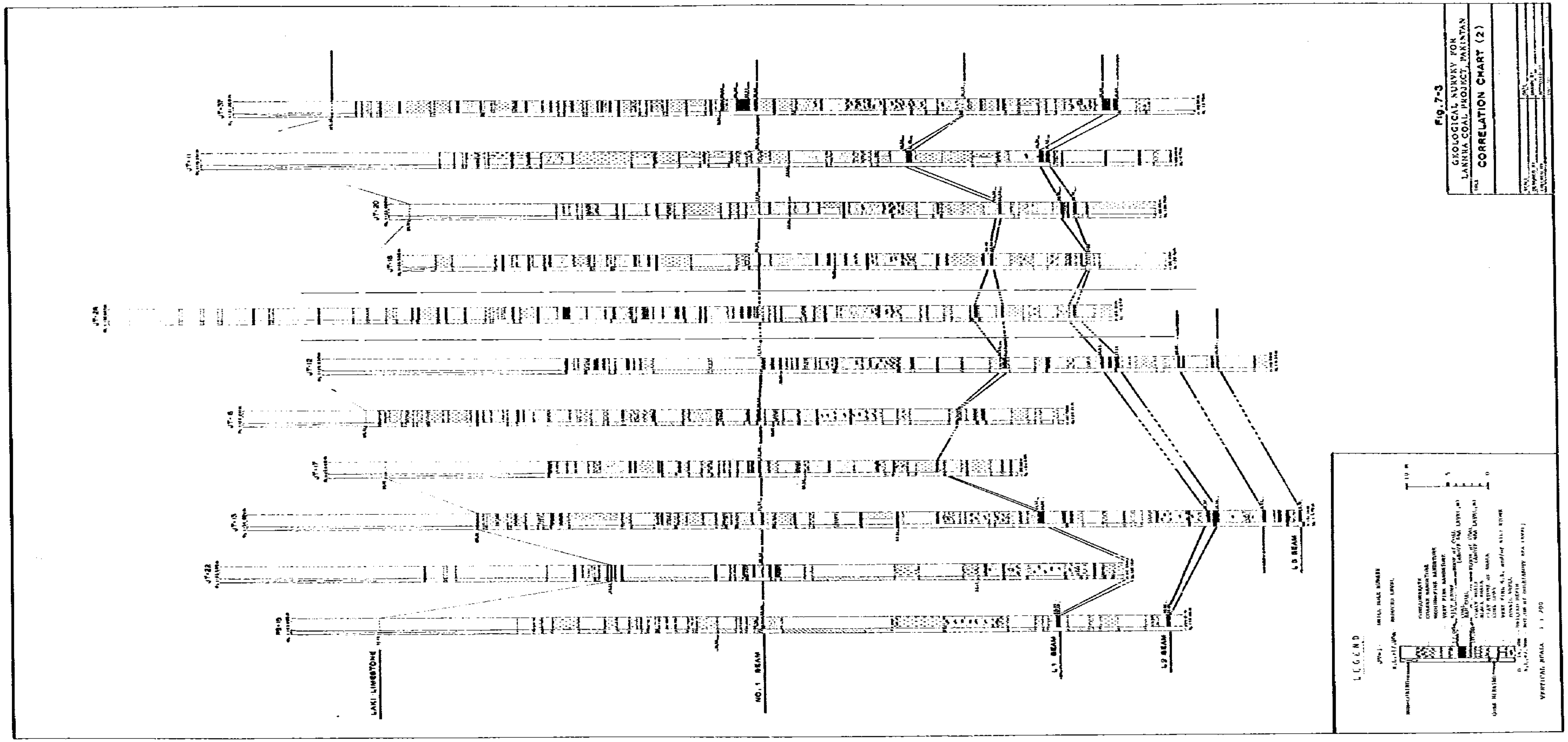


Fig.7-3
GEOLOGICAL SURVEY FOR LAKHRA COAL PROJECT, PAKISTAN
CORRELATION CHART (2)
LAKI LIMESTONE
NO.1 BEAM
L1 BEAM
L2 BEAM
L3 BEAM
LEGEND

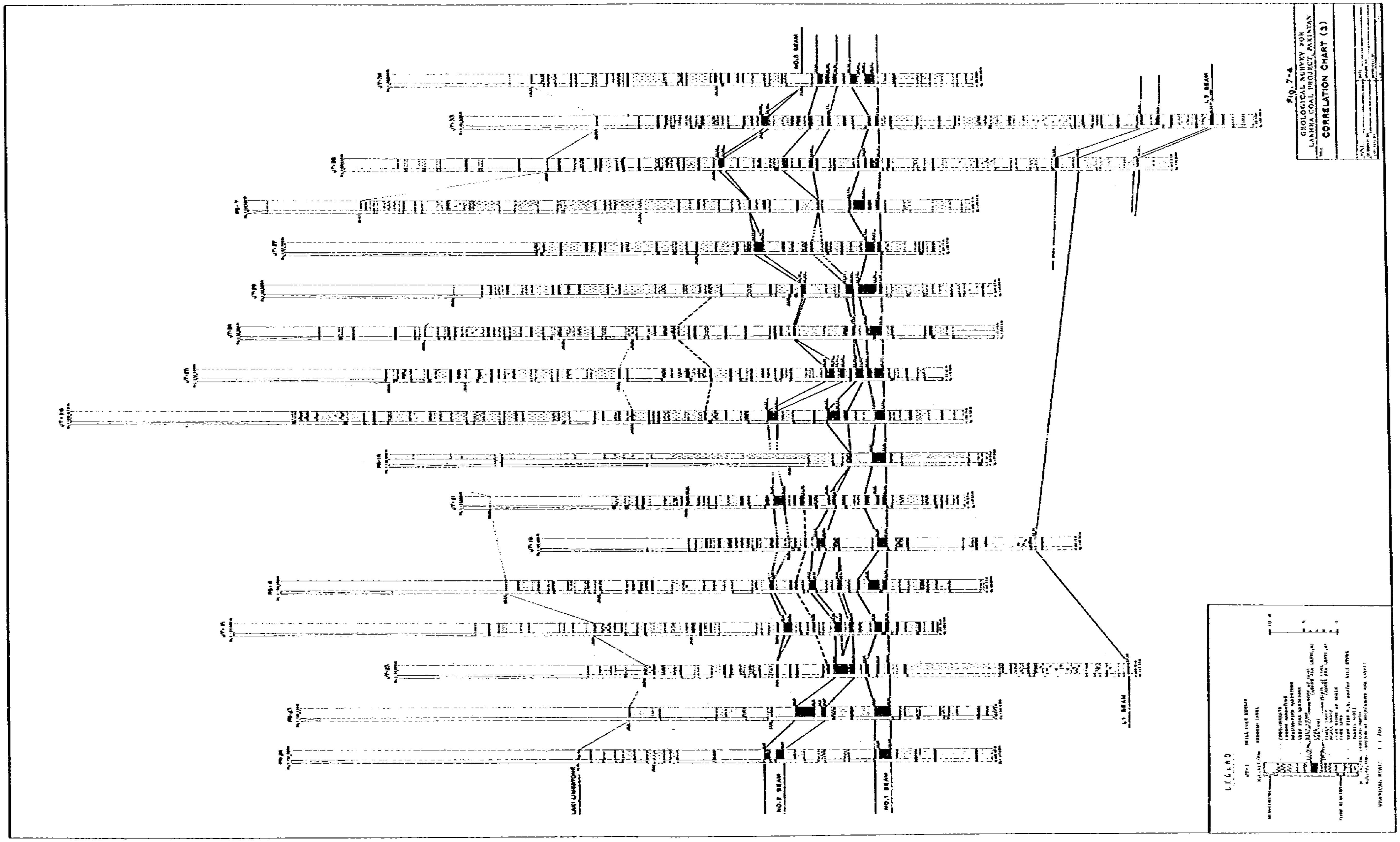


Fig. 7-4
GEOLOGICAL SURVEY FOR
LAKHRA COAL PROJECT, PAKISTAN
CORRELATION CHART (3)
LEGEND

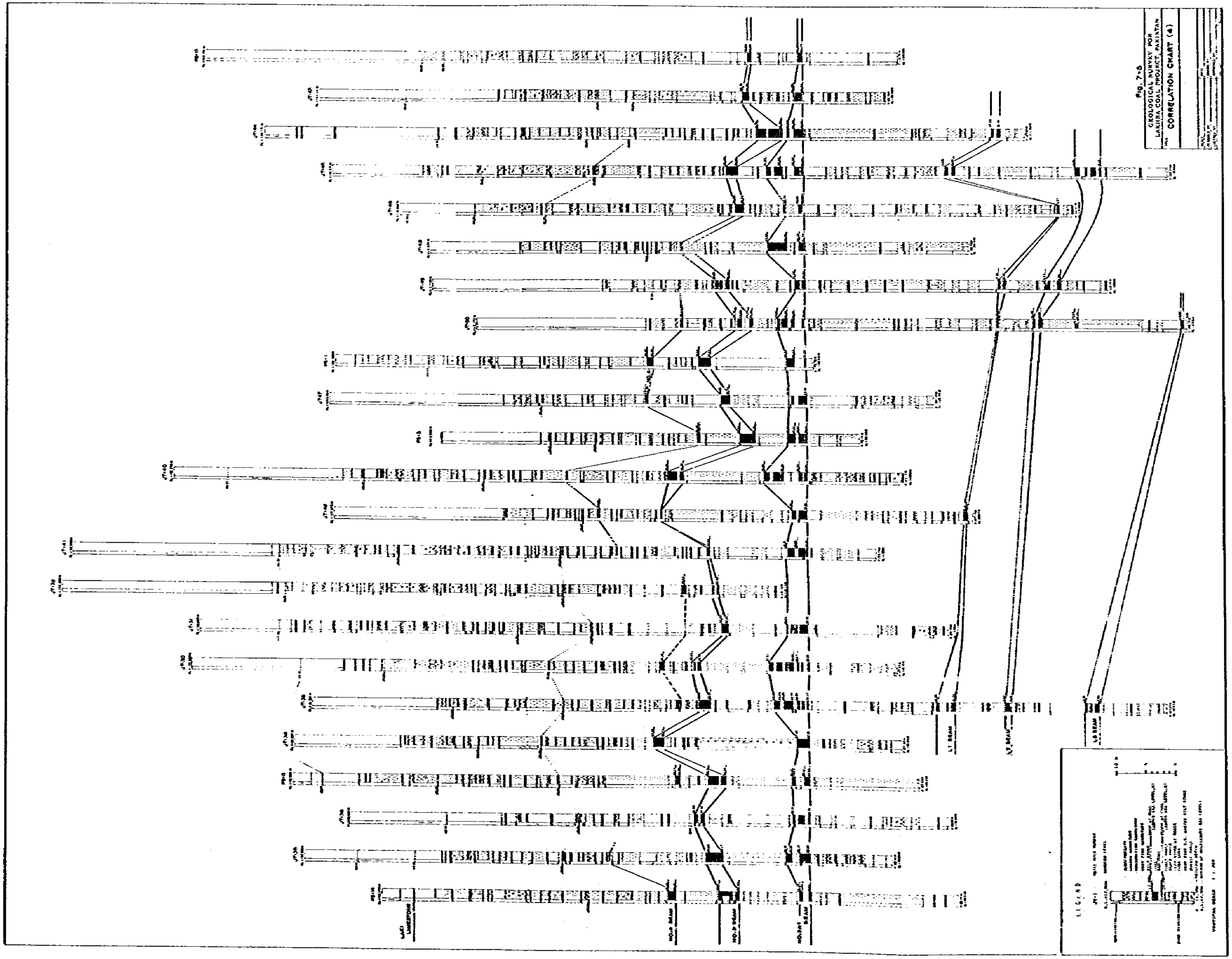


Fig. 7-5
GEOLOGICAL SURVEY FOR
LAKHRA COAL PROJECT, PAKISTAN
CORRELATION CHART (4)

STRUCTURE CONTOUR MAP, NO.1 SEAM (FLOOR)

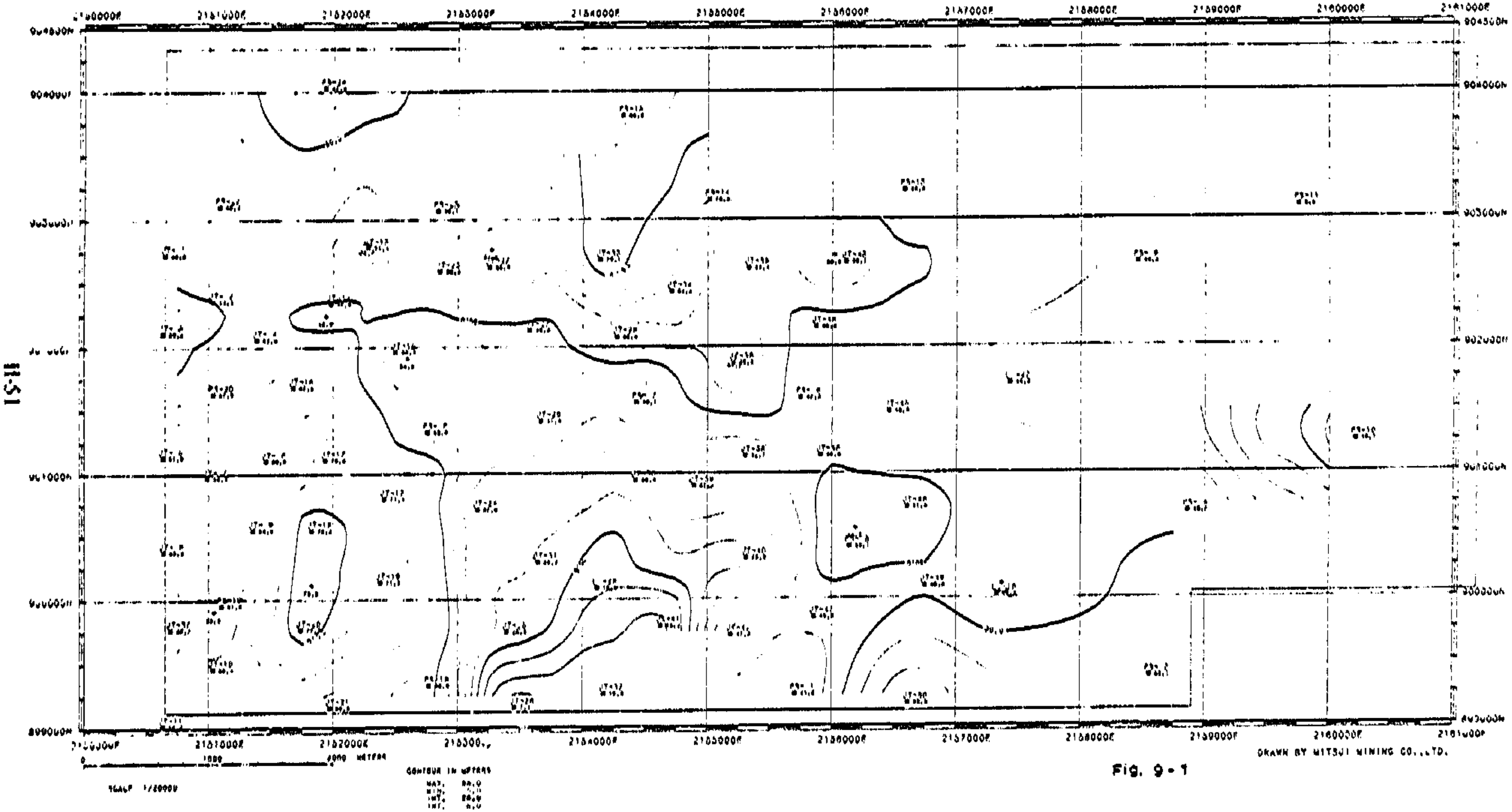


Fig. 9-1

SEAM CONTOUR MAP OF NO.2 SEAM (ROOF)

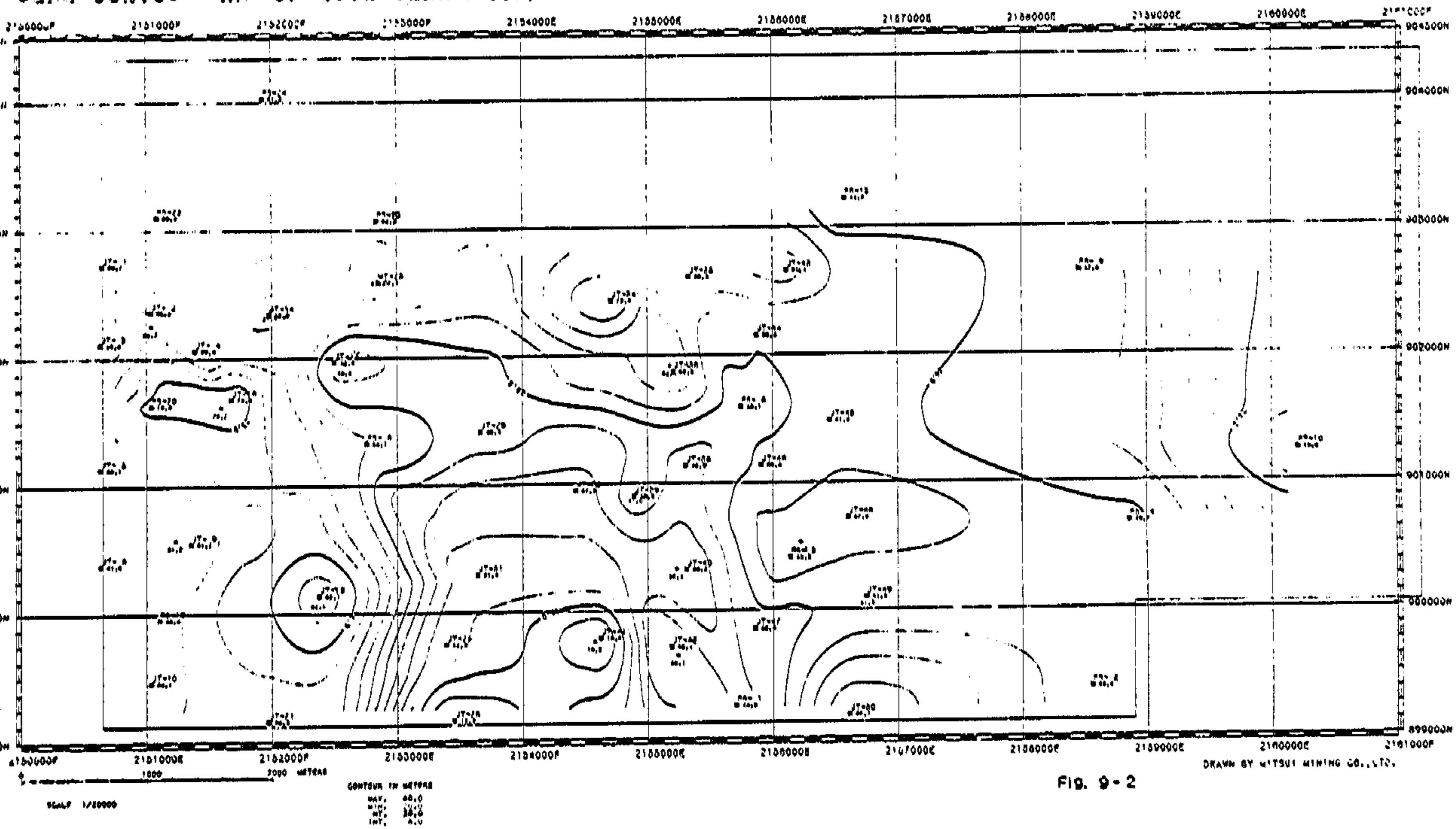
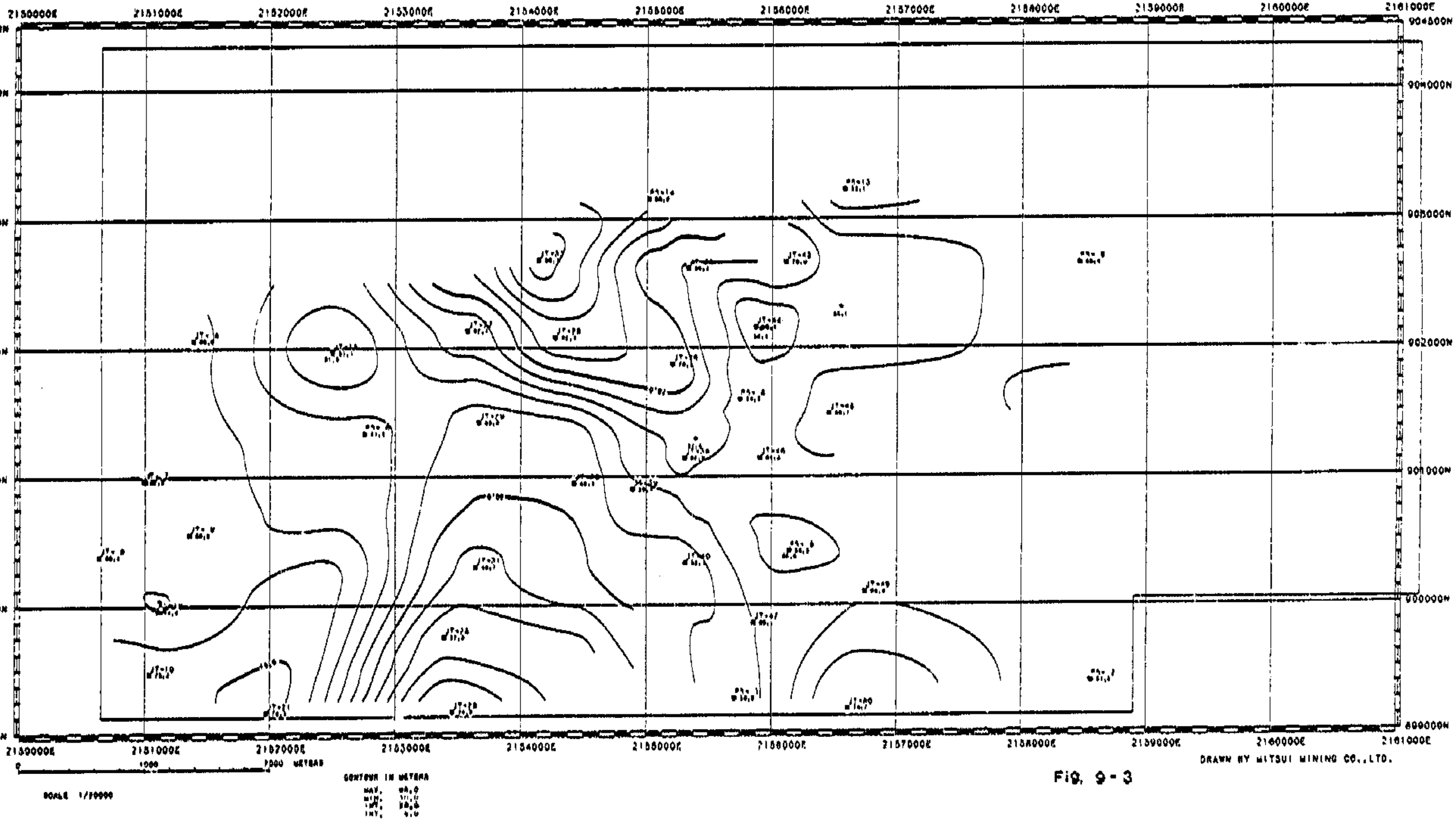


Fig. 9-2

SEAM CONTOUR MAP OF NO.3 SEAM (ROOF)



DRAWN BY MITSUI MINING CO.,LTD.

Fig. 9-3

SEAM CONTOUR MAP OF NO.5 SEAM (ROOF)

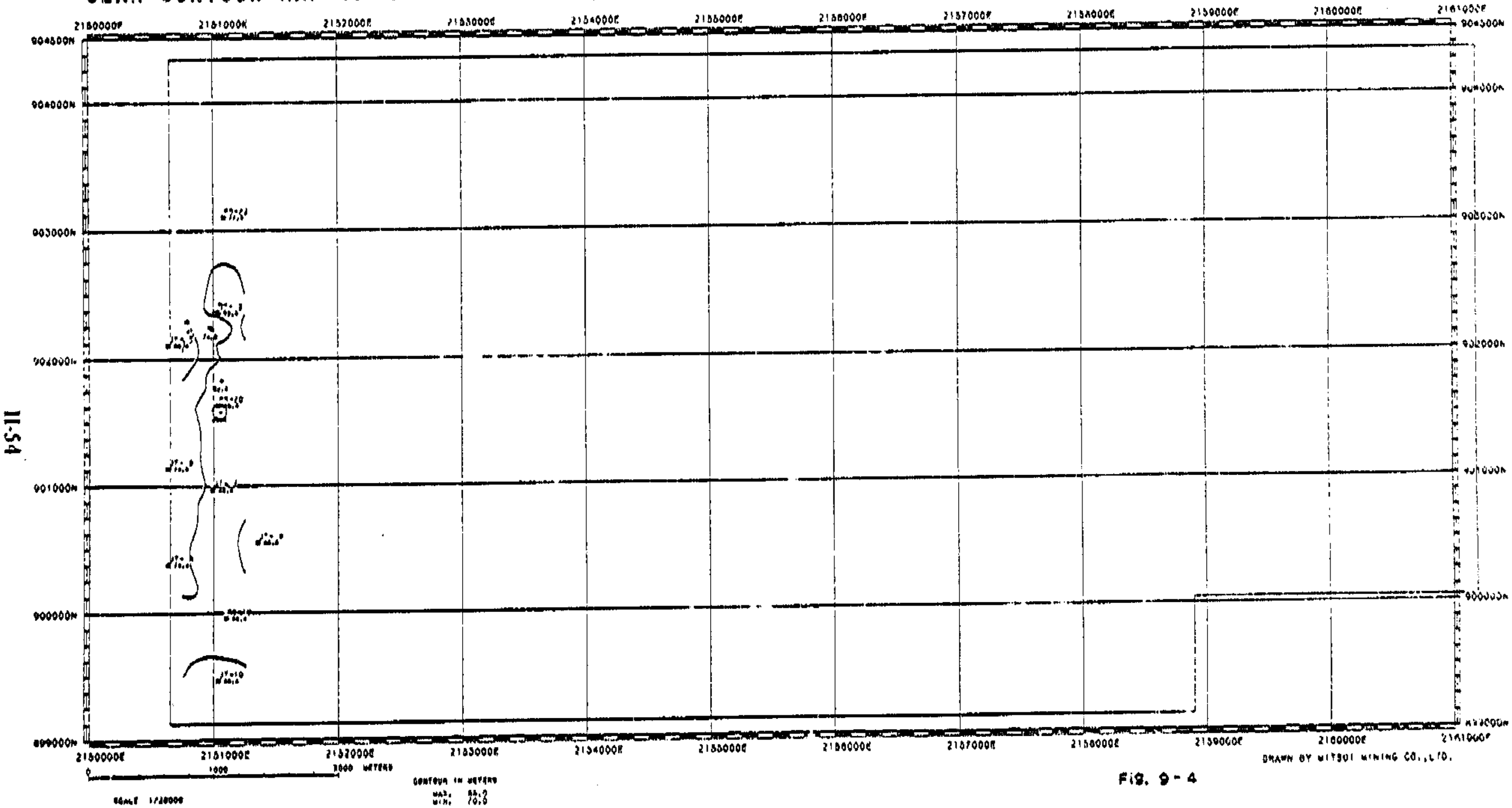


FIG. 9-4

DRAWN BY MITSUI MINING CO.,LTD.

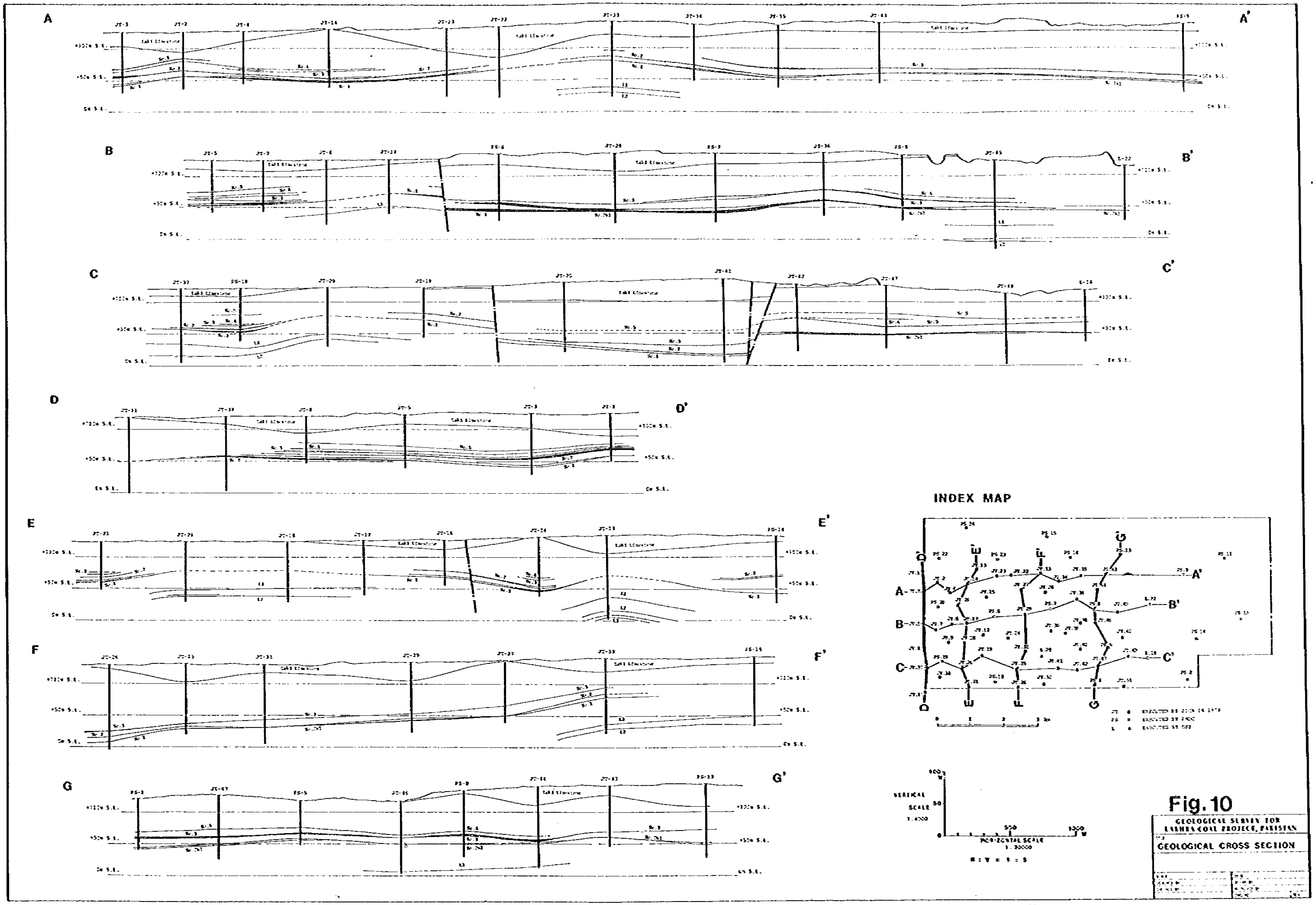

A
A'
B
B'
C
C'
D
D'
E
E'
F
F'
G
G'
INDEX MAP
VERTICAL SCALE 1:4000
HORIZONTAL SCALE 1:20000
GEOLOGICAL SURVEY FOR LAKHRA COAL PROJECT, PAKISTAN
GEOLOGICAL CROSS SECTION

Fig. 10