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GEOLOGY AND COAL RESOURCES OF THE SHEERNESS COALFIELD, SOUTH-CENTRAL ALBERTA

*** Volume I ***

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Although this study was based mainly on exploration data provided by Luscar Limited, Manalta Coal Limited, and Albert Power Limited, the results are not necessarily the same as interpreted by the companies for their respective subsets of data.

Detailed computer-generated resource estimates which have been compiled into a separate appended volume for the National Coal Inventory have been excluded from this release. These estimates, however, are fully summarized herein.

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GEOLOGY AND COAL RESOURCES

OF THE

SHEERNESS COALFIELD, SOUTH-CENTRAL ALBERTA

ABSTRACT

The commercially significant subbituminous coal resources within the lower Horseshoe Canyon Formation near Sheerness, Alberta, were examined in the context of Canada's National Coal Inventory program. A correlation framework comprised of four coal zones and two marker horizons was established using data from 1228 borehole sites, with an aggregate drilled penetration in excess of 22,000 m. This framework forms the basis of the geologic model which defines geometries and distributions of coal seams. A verified computer-processable database was produced and computer-assisted techniques were applied to all phases of the study The database and resource estimates can be readily updated and revised. In addition to providing the framework for estimating resources quantities, the geologic model can also be used to assist the planning of efficient resource exploitation and to predict geological conditions in laterally equivalent strata where less substantive data are available.

Factors which controlled the geometries and distributions of the coal seams were interpreted on the basis of observed lateral and vertical distributions of lithologies in interseam rock intervals. The Sheerness Coalfield is comprised mainly of strata deposited on the lower delta plain of a fluvially-dominated delta complex. Subaerial exposure of this delta plain resulted in peat accreting paludal conditions. Peat accretion was interrupted at various times by drowning and burial beneath noncoal clastic sediments, in most cases interpreted to be the result of overbank or crevasse splay flooding onto an interdistributary floodplain.

Resources totalling approximately 190 million tonnes of subbituminous C coal have been identified and categorized according to relative exploitation potential and assurance of existence. The composition and properties of the coal have been assessed on the basis of analysed coal quality attributes from 682 sampled plies. These samples were derived from 496 coal zone intersections from which drill cores were recovered.

INTRODUCTION

The Sheerness Coalfield, which is located 160 km east of Calgary, has hosted coal mining activities since 1910. Intensive exploration between 1964 and 1977 by Manalta Coal Limited and Luscar Limited, with the support of Alberta Power Limited, resulted in the delineation of a commercially attractive reserve of suitable quality coal to fuel a local electric generating plant.

In 1979 the Alberta government approved the development of a thermal power plant and associated mines near Sheerness. The mining approval permits the expansion of Manalta Coal Limited's current mining operations in the coalfield and the development of an adjoining mine by Forestburg Collieries Limited, a wholly-owned subsidiary of Luscar Limited. Coal production will ultimately fuel a 750 megawatt power plant operated by Alberta Power Limited (Energy Resources Conservation Board, 1979).

Further drilling was done by Luscar Limited in 1980 and 1981 which enhanced the resource definition and supplied additional geologic data for optimizing production plans. In 1981, Luscar Limited, Manalta Coal Limited and Alberta Power Limited provided the Geological Survey of Canada with their respective geologic data of the Sheerness Coalfield in support of the National Coal Inventory program. These data include borehole and topographic information, geophysical and drillers' logs of borehole penetrations, descriptions of recovered core and coal quality analyses. The data from six boreholes drilled by The Alberta Research Council were used to control the extrapolations of coal horizons beyond the intensely drilled central portion of the coalfield (Campbell, 1974). A geologic database was established by the Geological Survey of Canada which includes fundamental information interpreted from 22,319 m of logged drill penetrations from a total of 1228 exploration sites.

A study was made of the geometry of the coal seams, sedimentological features which controlled the coal formation and seam geometries, and coal quality distributions. This report provides estimates of coal resources within the coalfield and summarizes aspects of the geology pertinent to the geometry and distributions of the coal seams.

The study was conducted using computer-assisted techniques developed for the National Coal Inventory program. All data used for the study are stored in computer-processable form whereby revised geologic models and resource estimates can be expeditiously up-dated should additional data become available or resource estimating criteria change.

Acknowledgements

This study was modelled after a similar evaluation of the Dodds-Round Hill coalfield conducted by J.D. Hughes of the Geological Survey of Canada. The author is particularly grateful to Mr. Hughes for his advice and direction through all phases of this study.

The author gratefully acknowledges Luscar Limited, Manalta Coal Limited and Alberta Power Limited for providing proprietary data used for this study.

K.N. Nairn, K.E. Mottershead and D.W. Lepard, all of the Geological Survey of Canada, assisted in the computer aspects of the study. In addition to enhancing existing computer programs, they provided additional routines and programs for upgrading the methodologies. Summus Resource Evaluations Limited was commissioned to provide lithologic interpretations of borehole data and to initially enter borehole information in the Sheerness computer-accessible database. Subsequent data entry was done largely by Carol Boonstra. Discussions with J.D. Hughes and F.M. Dawson, among others, were constructive in the development of the geological and depositional models. John Thompson of the Cartography Section was particularly helpful in providing advice for improving the production of various figures. The author is grateful to all of these individuals.

Geographic Summary

The commercially significant coal resources of the Sheerness Coalfield lie within the 195 square kilometres of the Oyen NTS map-area (NTS Index No. 72M), bounded by UTM coordinates 443,000 m and 456,000 m east, and 5,695,000 m and 5,710,000 m north. The town of Hanna, which is located 25 km northwest of the coalfield, is the government and business centre of the area which is economically based largely on agriculture, with some coal mining and oil and gas activity. Hanna was a divisional point on the C.N.R. between the main line and a spur which runs across the east side of the coalfield (Figure 1).

The area is generally flat with the exception of a "badlands" feature in the northwest which delineates an abrupt rise in relief of approximately 25 m, to the northwest. Topographic features of smaller scale are mainly the result of stream incisions or Pleistocene glaciation (Figure 2). The area is mantled by a layer of unconsolidated silt, sand and till which averages 5 m thick.

The area lies in the treeless prairie vegetation region of southern Alberta where growth of short prairie grasses predominates and tree growths are restricted to areas along watercourses. The agricultural land over the coalfield has been devoted to both livestock and crop farming.

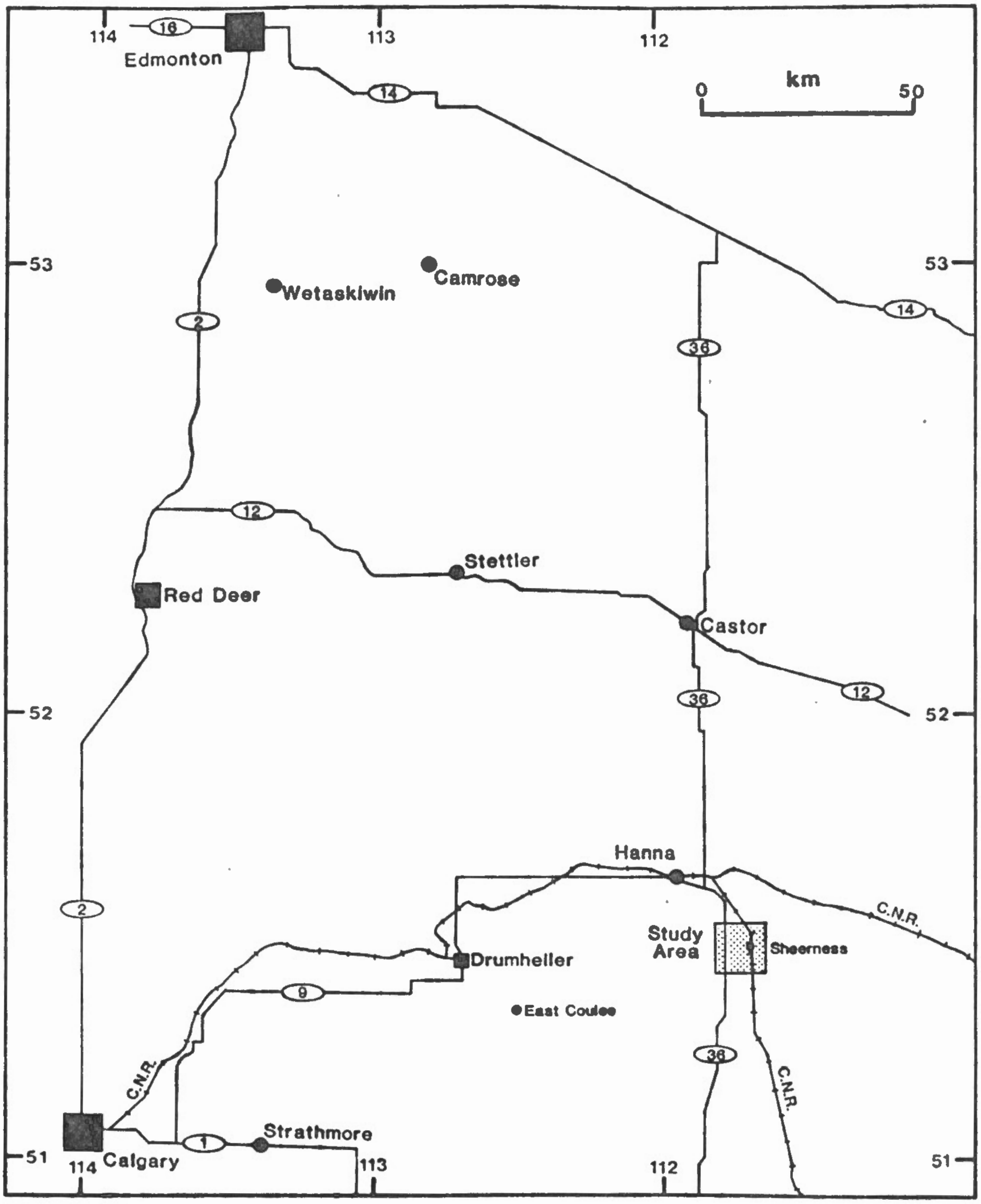


Figure 1.

Location of Sheerness Coalfield.

Exploration History and Available Data

Seventeen mines have operated in the Sheerness Coalfield since 1910. These operations have varied in scope and include surface and underground mines. Commercially, the most important mining of the region was confined to the immediate vicinity of the hamlet of Sheerness where coal was supplied to the Canadian National Railway. Small mines operated intermittently in the region for supplying coal to the town of Hanna on a demand basis (Allan, 1936). Only one of the mines, the Montgomery Mine, is still operating and, under the direction of Manalta Coal Limited, produces less than 100,000 tonnes per year (Energy Resources Conservation Board, 1984). Allan (op. cit.) described several of the mining sections and provided analyses of coals from exposed mine faces.

An indication of the intensity of exploration conducted since 1962 and a summary of borehole data available for this study are provided in Table 1. The distribution of boreholes included in the study and locations of past mining operations are illustrated in Figure 3. Borehole data from 1228 sites and an aggregate penetration of 22,319 m were compiled and studied. Where a location was drilled more than once, data from only the most representative borehole at that location were included in the database. The analytical data of 682 coal samples from 327 sites across the coalfield were used to define the quality of coal within the resource.

Available data from drilling prior to 1974 consisted of logs of cuttings from rotary boreholes. The data from Alberta Power Limited's 1974 drilling included descriptions of both rotary drill cuttings and recovered core. The major coal seams and enveloping rock were cored during this program and the first modern analyses of coal quality resulted. All of the 1079 sites represented in the database from drilling during the period 1976 to 1981 included a complete suite of natural gamma, resistance and gamma-gamma density geophysical logs in addition to descriptions of rotary drill cuttings made by the drillers. Twenty-four per cent of these locations had associated caliper geophysical logs available. Coal quality of the main coal intersections was tested at approximately twenty-seven per cent of all locations drilled. The average spacing of locations drilled between 1976 and 1981 was 200 m.

In addition to the surveyed coordinates for all borehole locations, topographic maps at a scale of 1:4800 with 1.52 m contour intervals were provided for the most intensely drilled central portion of the coalfield. Outside of this area, National Topographic System (NTS) 1:50,000 scale maps with 7.62 m contour intervals were used (Figure 2).

TABLE 1

Summary of drilling and available borehole data for the Sheerness Coalfield

Year	Holes* Drilled	Holes Available	GSC Computer Database: Lithologies – Sites Represented	Lithologies – Depth (m) Represented	Coal Quality – Sites Represented	Coal Quality – No. of Samples	Company
1962	13	13	6	192	-	-	A.R.
1964	463	38	29	527	-	-	Manalta
1966	25	88	87	1146	-	-	Manalta
1972	111	-	-	-	-	-	A.P.L.
1973	30	-	-	-	-	-	Can Pac
1974	95	89	27	362	70	107	A.P.L.
1974	3	-	-	-	-	-	W.L.S.
1976	174	232	142	3854	88	164	Luscar
1976	1	-	-	-	-	-	A.E.
1976	1	-	-	-	-	-	Manalta
1977	552	530	526	8875	56	152	Luscar
1977	14	-	-	-	-	-	McEwen
1978	25	-	-	-	-	-	Manalta
1978	6	-	-	-	-	-	A.P.L.
1980	331	339	287	5741	86	211	Luscar
1981	134	133	124	1622	27	48	Luscar
Totals	1978	1439	1228	22319	327	682	

* per Energy Resources Conservation Board (open file)

A R. - Alberta Research
A.P.L. - Alberta Power Limited
W.L.S. - Western Land Services Co.
A.E. - Alberta Environment
McEwen - McEwen Melville

Geologic Overview

The coal resources of the Sheerness Coalfield are contained within Upper Cretaceous strata of the lowermost 70 m of the Horseshoe Canyon Formation. These strata are part of an eastward-thinning progradational sequence of mainly fluvial-deltaic sediments deposited over central and southern Alberta during the retreat of the Bearpaw Sea in Late Campanian and Maestrichtian time.

The predominantly nonmarine coal-bearing strata which include sandstone, siltstone, shale and coal lithotypes, were deposited during the period of transition between the marine sedimentation of the underlying Bearpaw Formation and the continental sedimentation of the Horseshoe Canyon Formation (Shepheard and Hills, 1970). Studies of correlative strata in the surface section along the Red Deer River valley between East Coulee and Drumheller, 65 km west of Sheerness, by Shepheard (1969), Gibson (1977) and Rahmani (1981 and 1982), among others, and a detailed subsurface study at Dodds-Round Hill, 170 km to the northwest, by Hughes (1984), are relevant to the understanding of local depositional environments, depositional processes and the cyclic character of deposition during this transition period (Figure 1).

The Horseshoe Canyon Formation averages approximately 250 m thick where a complete section is present west of Drumheller. Thirteen coal seams have been extensively traced in this region and are important marker horizons in the formation. The lower 70 m of the formation exhibit sedimentological characteristics which are common to lower delta plain depositional environments (Gibson, 1977). Shepheard and Hills (1970) recognized several deltaic subenvironments within the lower 60 m of the formation near Drumheller, and proposed a depositional framework whereby an easterly prograding deltaic complex, supplied with clastics from uplifted areas in the Cordillera, resulted in the regressive deposits of the Horseshoe Canyon Formation at the margins of the retreating Bearpaw Sea.

The Horseshoe Canyon Formation conformably overlies the marine deposits of the Bearpaw Formation. The Bearpaw Formation is characterized by a series of coarsening-upward cycles of predominantly shallow marine deposits, and rests conformably on nonmarine sandstones of the Judith River Formation (Given and Wall, 1971). Habib (1981) examined these cycles and proposed a shallow marine depositional framework whereby series of coarsening-upward prodelta, delta front and distributary mouth bar facies were repeated as a result of episodic fluctuations of water depth (i.e. alternating periods of marine transgression and regression). The contact between the Bearpaw Formation and the Horseshoe Canyon Formation is placed at the top of the uppermost shale unit of the Bearpaw Formation and at the base of the lowermost continental sandstone of the Horseshoe Canyon Formation (Irish, 1970). The above stratigraphic relationships are summarized in Figure 4.

APPLIED STRATIGRAPHIC NOMENCLATURE

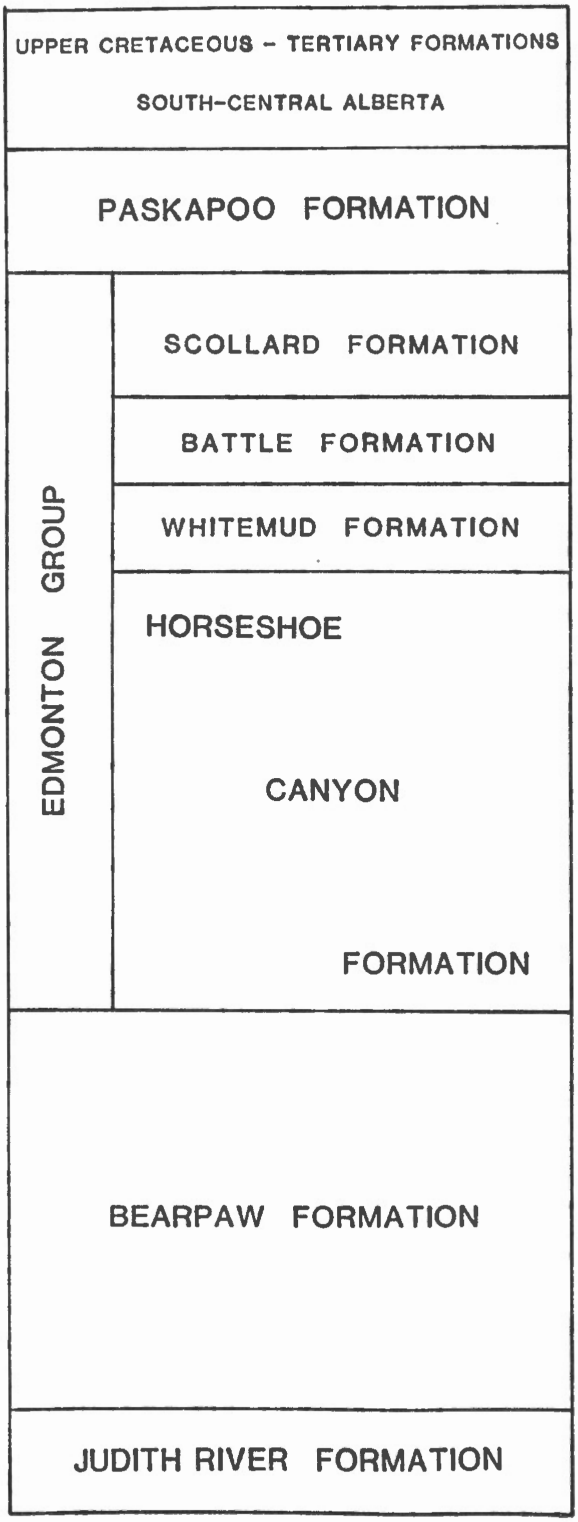


Figure 4.

(after Gibson, 1977)

The combined effects of erosion and a regional dip of 2 m/km in a west-southwesterly direction have resulted in the subcropping of the contact between the Bearpaw and Horseshoe Canyon formations approximately 8 km east of Sheerness. The suggestion by Allan (1936 and 1943) that the seam mined by stripping operations near Sheerness corresponds to the "lowest workable seam" (No. 1 seam) near Drumheller appears correct, based on the results of this study. The suggestion by Campbell (1974) that "Sheerness coal" is stratigraphically equivalent to seams 5 to 7 at Drumheller is apparently based on the belief that the coal at the base of the "badlands" is the same as the coal being mined at the Montgomery Mine, rather than the Richdale seam, as demonstrated by this study. The suggestion by Bihl (1970) that the "Sheerness coal seam" is probably equivalent to the Drumheller No. 7 coal seam is similarly untenable and was apparently based on an effort to show that the seam is not stratigraphically equivalent to seams in the upper part of the Edmonton Group.

The location of the Sheerness Coalfield with respect to Upper Cretaceous and Tertiary formations of central Alberta is provided in Figure 5.

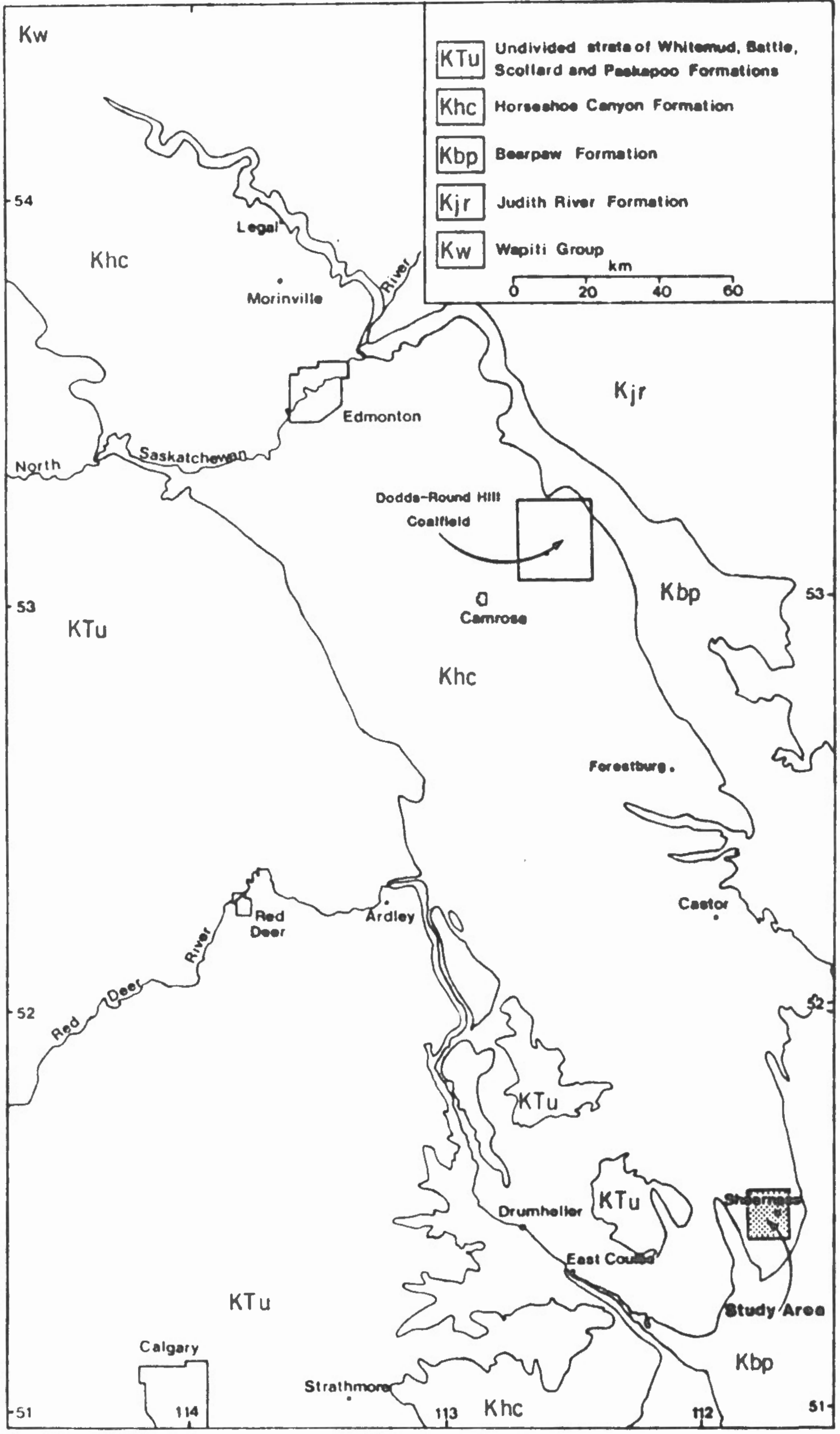


Figure 5.

Geologic map of central Alberta.

(from Hughes, 1984)

Coalfield Modelling

Six coal zones in the Sheerness Coalfield were correlated using borehole data. These zones are identified in stratigraphically ascending order as Sunnynook, Sheerness, Roselynn, Richdale, Taplow and Hanna (Figure 9). Wherever possible, individual coal seams within the zones were correlated. Two persistent shale horizons were also correlated: Marker 1, lying 10-15 m below the Sunnynook coal zone, and Marker 2, between the Richdale and Roselynn coal zones. The correlated coal zones and marker horizons provided the basis for establishing the geologic framework of the coalfield from which a geologic model was established.

The geometries of coal seams and interseam rock units as defined by this model provided the basis for evaluating the coal resources. An understanding of the factors which controlled the variations in shape of the coal seams is of economic significance in designing programs to further explore the coalfield and laterally equivalent strata, and in planning mine developments.

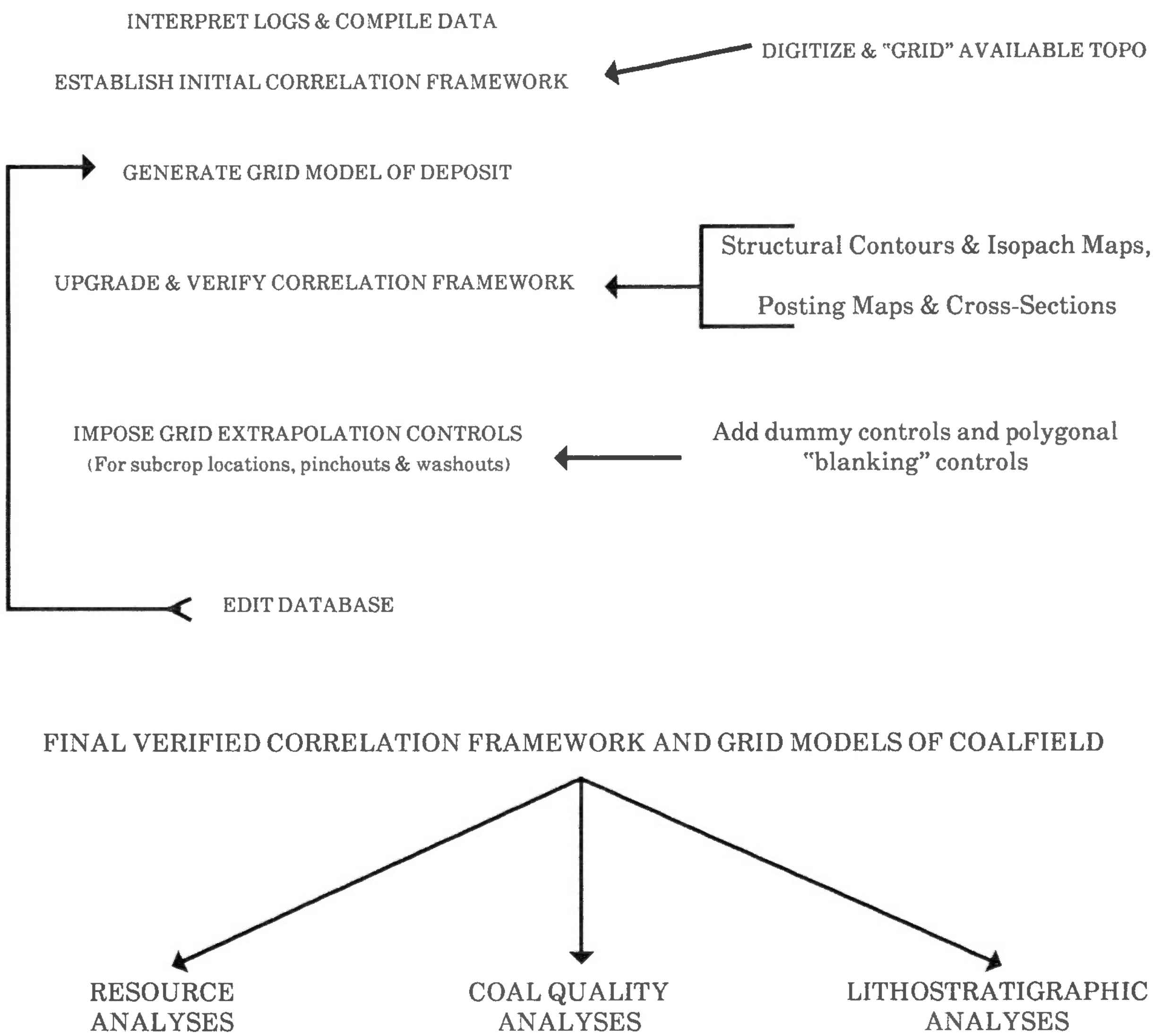
METHODOLOGY

It was decided from the outset of the National Coal Inventory program in 1972 that the large quantity of data requiring processing and evaluation could be most effectively handled using computer-assisted techniques (Irvine and Williams, 1978). The initial computer-based systems for the storage, retrieval, manipulation and display of coal resource data were applied to the evaluation of coal resources of southern Saskatchewan (Irvine et al., 1978). The computer-assisted procedures are being continually upgraded and expanded by the Coal Resource Evaluation Section of the Geological Survey of Canada, for the evaluation of Canadian coalfields. The Sheerness Coalfield has been evaluated using the current procedures and, although similar to those described by Hughes (1984), the methods applied specifically to Sheerness are briefly outlined below. For a more detailed discussion of computer-based procedures utilized by the Geological Survey of Canada for coal deposit assessment, the reader is referred to Hughes (in prep.).

The Sheerness resource evaluation is based on interpreted borehole data stored in an IMAGE database on an HP3000 computer. This geologic database includes the position and correlation of intersected lithologic units, in addition to borehole survey information and coal quality data. The database can be interrogated using a variety of computer programs to produce displays and quantitative analyses pertinent to the verification of data and evaluation of the coal deposits. A summary of procedures used to assess the resources is illustrated in Figure 6.

FIGURE 6

Resource assessment procedures



Interpretation and Compilation of Borehole Data

All geologic data in the database were derived from boreholes. These data in a raw state are expressed in one or more of the following forms:

Geophysical logs	-	natural gamma	(88%)*
	-	resistance	(88%)
	-	gamma-gamma density	(88%)
	-	caliper	(21%)
Core logs	-	partial hole coring of main coal-bearing sections	(27%)
Drill cutting logs	-	rock type assessments by drillers, from rotary drill cuttings	(100%)

* Figures in brackets refer to the percentage of sites drilled which have data represented in the respective forms.

All lithologic interpretations and initial correlations from the hard copy data were performed under contract by Summus Resource Evaluations Ltd. using the following procedures. After data for a borehole were collated and examined, the best information was used to subdivide the borehole into discrete lithologic units. The eighteen lithologies recorded in the Sheerness database are shown in Table 2.

Geophysical logs allowed the best resolution of lithologic detail and provided the most reliable means of correlating laterally persistent lithologic units between holes through recognition of signature responses. As the geophysical logs are uncalibrated analog records showing relative variations in selected geophysical responses between the lithologic units penetrated, the interpretation process required the determination of relative response levels of the various lithotypes in each borehole. Coal, shale/bentonite and concretionary units were identified as anomalous extremes of geophysical response in one or more of the logs. After examining overall background responses of all logs for an entire hole, threshold gamma response levels of the sand-sized and clay-sized end members were determined. The relative grain size of the sand-sized end member was established using available core descriptions. Noncoaly lithotypes between the sand-sized and clay-sized thresholds were classified according to relative natural gamma response. The boreholes were subdivided into intervals of uniform gamma response and each interval was assigned a lithologic identification based on its relative gamma response. Lithotypes were then recorded on the basis of uniform response within the limits of respective subdivisions.

A combination of gamma, resistance and density logs was used to classify and position coaly lithotypes. Coal responds anomalously to all three measurements by registering low levels of gamma radiation, high resistance to electrical current and low molecular density. Weathered coal registers similar gamma and density anomalies but a very weak or absent resistance anomaly. Shaly coal and coaly shale are marked by a progressive weakening of anomalous responses of all three logs with respect to coal values. Carbonaceous shale is normally recorded as a coal parting or contact unit associated with coal or shaly coal. Its classification is based on gamma and resistance responses trending toward those of shale, and density responses at levels between those of coal and the noncoaly background.

TABLE 2

Lithologic units in Sheerness database

Lithologic unit	Group
TILL	NON-COALY LITHOTYPES
CONCRETION	NON-COALY LITHOTYPES
COARSE GRAINED SANDSTONE	NON-COALY LITHOTYPES
MEDIUM GRAINED SANDSTONE	NON-COALY LITHOTYPES
FINE GRAINED SANDSTONE	NON-COALY LITHOTYPES
VERY FINE GRAINED SANDSTONE	NON-COALY LITHOTYPES
SANDY SILTSTONE	NON-COALY LITHOTYPES
SILTSTONE	NON-COALY LITHOTYPES
SHALY SILTSTONE	NON-COALY LITHOTYPES
SILTY SHALE	NON-COALY LITHOTYPES
BENTONITIC SHALE	NON-COALY LITHOTYPES
BENTONITE	NON-COALY LITHOTYPES
SHALE	NON-COALY LITHOTYPES
CARBONACEOUS SHALE	COALY LITHOTYPES
SHALY COAL	COALY LITHOTYPES
COALY SHALE	COALY LITHOTYPES
WEATHERED COAL	COALY LITHOTYPES
COAL	COALY LITHOTYPES

Contacts between lithotypes were positioned by considering points of inflection on the geophysical response curves. Recognizing that curves are response records from an upward moving sonde, the initial inflection of response levels beyond those of the noise range of a lithotype signified the encountering of a different lithotype. Geophysical logs allowed identification of lithotypes with a minimum thickness of 0.1 m for geophysically sensitive units such as coal, bentonite and concretions.

The contact between surficial material and bedrock in boreholes was positioned on the basis of both geophysical data and drillers' reports. Caliper logs, where available, generally showed a clear distinction between bedrock and overlying unconsolidated materials which have been collectively termed "till". The heterogeneity of glacial till was reflected by erratic density responses. Clay minerals which are often washed from tills resulted in gamma responses lower than those of adjacent bedrock.

An example of interpreted geophysical logs is provided in Figure 7.

Where geophysical logs were unavailable, lithologic units were defined using descriptions of rotary drill cuttings and/or recovered core, and were found to be somewhat less reliable than those interpreted from geophysical logs.

The importance of consistency in interpreting the type and position of lithotypes was emphasized by interpreting holes in spatial order. This approach also allowed the general correlation of coal horizons in adjacent holes during the initial interpretation of raw data.

All laterally persistent coaly intersections were assigned membership to a correlatable coal "zone". A coal zone was defined as a group of associated coaly beds which occur at about the same stratigraphic position but within which separate beds might split, coalesce, thicken or pinch out. Each coal zone was assigned a name, and correlatable beds within a zone were assigned letter modifiers in a manner described by Irvine et al. (1978). A schematic profile of correlated beds within a coal zone is provided in Figure 8.

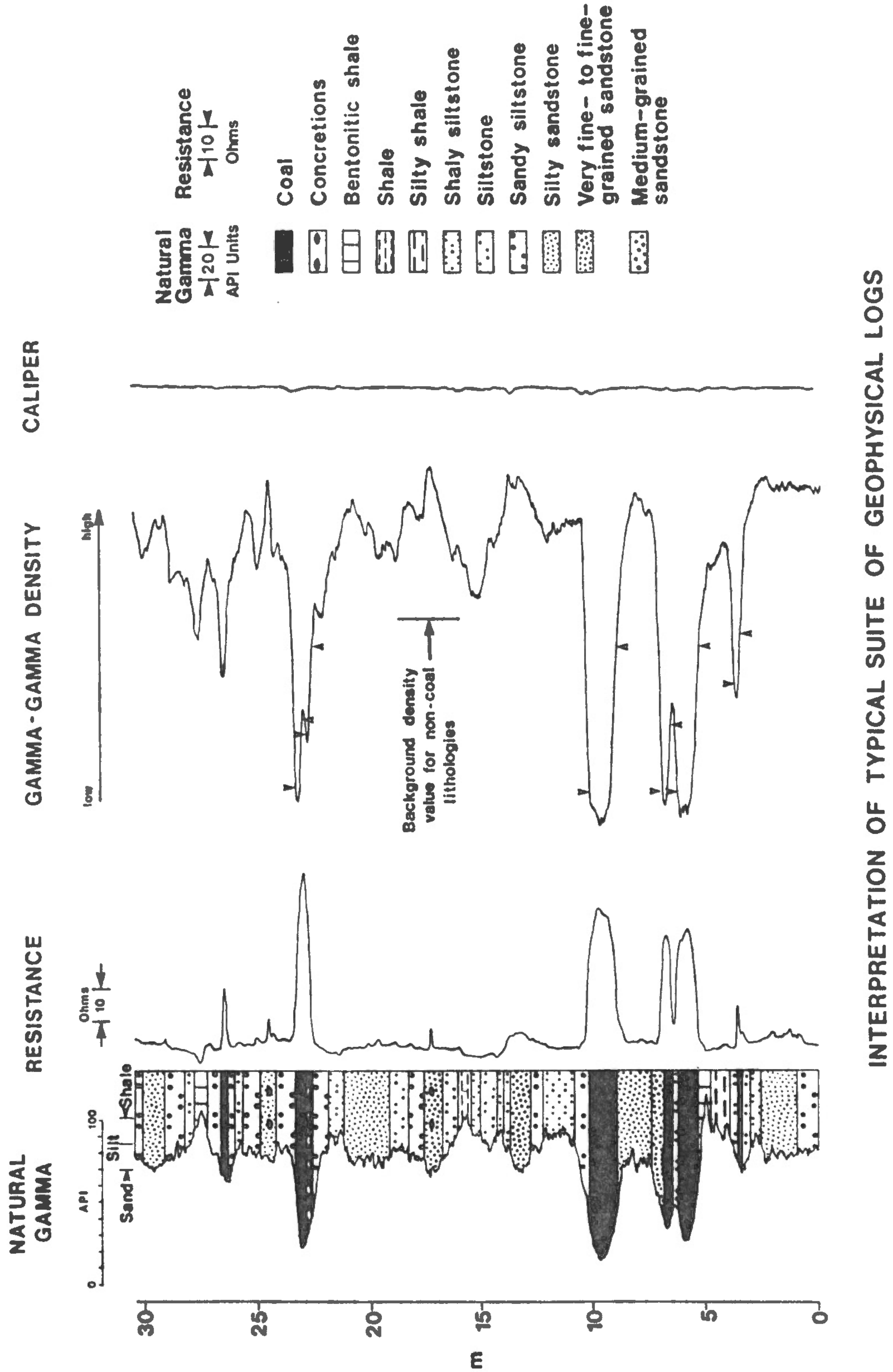


Figure 7.

(from Hughes, 1984)

SCHEMATIC PROFILE OF A CORRELATED COAL ZONE

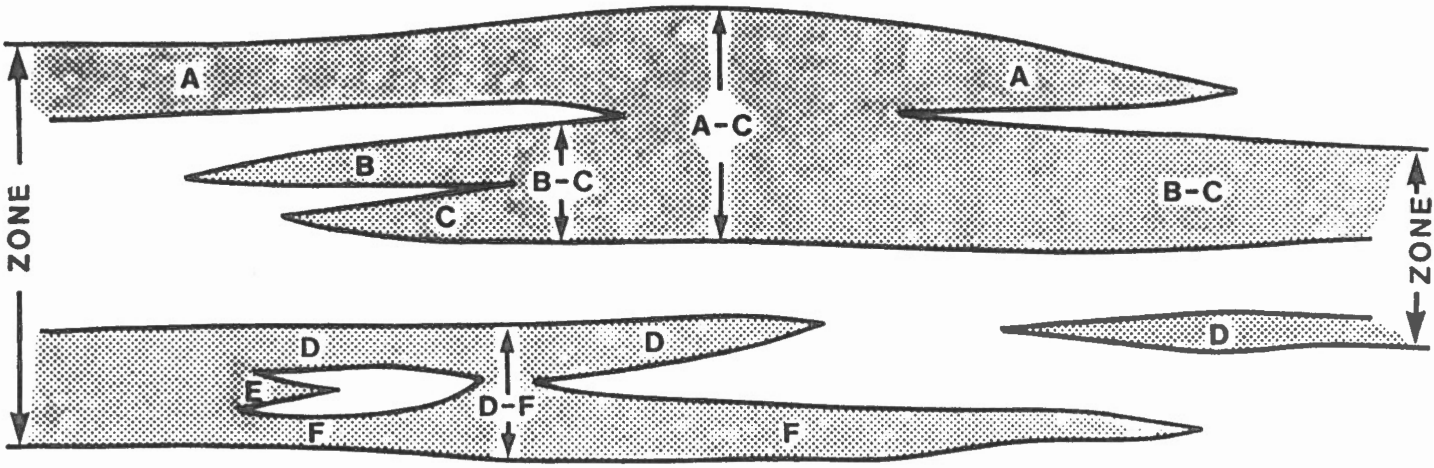


Figure 8.

(from Irvine et al., 1978)

Data Storage

All interpreted geologic data, including preliminary coal zone correlation and borehole survey information were stored within an IMAGE database on an HP3000 computer. Analytical data pertaining to the coal quality of sampled plies, which were also stored in the database. are the subject of a separate discussion in a following section. The database comprises three sets of data containing identification, lithology and analytical data. The types of data which can be stored in each set are shown in Table 3.

Specialized editing programs have been designed to build and maintain the database. In addition to allowing the entry, modification and display of data, these programs provide checks of data being entered against a dictionary of valid names or numeric ranges.

After storing fundamental geologic and survey information in the database, a rigorous computer-assisted procedure was initiated for verifying data and establishing a comprehensive correlation framework which formed the basis upon which the geologic model was developed.

Data Retrieval

The database can be interrogated using a query language to retrieve information based on user-defined selection criteria. Other programs have been designed to dump specific information from the database into sequential data files for use with other software packages.

Data Management and Display

The data were processed using a variety of software packages to produce maps, cross-sections, perspective block diagrams and graphic lithologic sections of boreholes, and to perform statistical analyses. In addition to the commercially available Surface II (Sampson, 1978), Terraplot (Terradata, 1981) and CROSEC (DeSouza and Stevens, 1980), several inhouse programs developed by C.F. Stevens and K.E. Mottershead were used. The application of these systems to coalfield resource evaluation has been described by Hughes (1984 and in prep.). A summary listing of the main computer software systems used for this study, showing primary applied functions is provided in Table 4.

Many of the computer programs utilized require the values of spatially distributed variables to be determined at the nodes of regular orthogonal grids. As all grids generated have nodes at the same geographic location, different variables could be compared and arithmetically manipulated. Values at grid nodes were determined by interpolating or extrapolating from the irregularly spaced borehole data. Several gridding algorithms available in the Surface II system were used in this process. Types of variables considered in this study include elevations of the top and bottom of correlated horizons, elevation of the topographic surface, net coal thickness, overburden thickness, coal ash content, coal unit heat value, among others.

TABLE 3

Data base items

IDENTIFICATION (for each borehole)	LITHOLOGY (for each lithologic unit)	PLY ANALYSIS (for each ply analysis)
HOLE IDENTIFICATION	HOLE IDENTIFICATION	HOLE IDENTIFICATION
LOCATION (SURVEY)	LITHOLOGY	LAB IDENTIFIER
COLLAR ELEVATION	FORMATION	SAMPLE IDENTIFIER
DEPTH DRILLED	CORRELATION IDENTIFIERS	SAMPLING METHOD
LOGS RUN	- ZONE NAME	RECOVERY (%)
TYPE OF DRILLING	- MODIFIER NAME	INCLUDED PARTING
GEOLOGIST	TOP AND BOTTOM DEPTHS	ZONE NAME
SOURCE OF DATA	TOP AND BOTTOM ELEVATIONS	MODIFIER NAME
	THICKNESS	TOP AND BOTTOM DEPTHS
	AVAILABLE DETAILED LOGS	TOP AND BOTTOM ELEVATIONS
	SEQUENCE NUMBER	THICKNESS
		PROXIMATE DATA
		ULTIMATE DATA
		ASH COMPOSITION DATA
		ASH PROPERTIES DATA
		HARDGROVE
		SPECIFIC GRAVITY

TABLE 4

Applied Computer Software

SURFACE II	- gridding, posting, contouring, error analysis & perspective block diagrams
TERRAPLOT	- posting & "windowing" grids
GPR	- posting
LITHLOG	- graphic lithologic strip logs
MAUDE	- grid manipulation
CROSEC	- constructing cross-sections
PERCENT	- calculating aggregate thickness or percentage of lithologies between surfaces
TOTAL	- aggregating coal beds for net coal thickness calculation
TONS	- calculating resource quantities (incrementally)
COMBINE	- compositing ply analyses of coal quality
MARKOV	- testing for Markovian tendencies (vertical geologic patterns)

Grid Generation

Many computer-based procedures are available for the estimation of values at grid nodes from irregularly spaced surrounding data. The Surface II procedure utilized in this report is described below:

> Initially, a search was performed around each control point and qualifying data were used to fit a weighted trend surface passing through each control point. A second search was then performed to identify qualifying data around each grid note. Trend surfaces of qualifying data were projected to the grid node and a value was estimated using a distance-weighted average of these surface projections.
>
> The method applied to identify data points to be used for trend surface estimation and projections involved searching for data points in circular areas of variable radius around each control point or grid node. The radius of the search area was increased incrementally a maximum of four times until at least eight points were found. The search failed if an insufficient number of data points were found after examining the maximum search area. If more than twelve points were found within a required search area, the nearest twelve were used. The initial search radius (R_i) was set
>
> $$R_i = \sqrt{\frac{A}{\pi}}$$
>
> $$\text{where } A = \frac{\text{total map area}}{\text{total number of data points}} * 8$$
>
> The maximum search radius (R_m) was set to
>
> $$R_m = \sqrt{\frac{A}{\pi}}$$
>
> $$\text{where } A = \frac{\text{total map area}}{\text{total number of data points}} * 60$$
>
> Where a search failed around a data point or grid node, a blank value of $-1 * 10^{30}$ was assigned to that location.
>
> The distance weighting function (W) applied in this study was
>
> $$W = (1 - (D / (1.1 * D_{max})))^2 \; / \; (D/(1.1 * D_{max}))^2$$
>
> where D = distance to sample point
> D_{max} = distance to most distant qualifying sample point

During the initial phases of this study, when data entry and correlation errors had not yet been identified and corrected, grid nodes were established at 200 m intervals. This resulted in the creation of grid matrices having 66 columns and 76 rows over the area of 13 km by 15 km. The interval was later reduced to 100 m to provide more precise representation of variables during the analyses of geologic features. Grid cells of 50 m square were used initially for determining resource quantities. After establishing that resource quantities estimated from 100 m square grid cells were essentially identical to those estimated from 50 m square cells, gridding at 50 m intervals was discontinued.

Grid Manipulation

Spatially distributed variables represented by a common set of grid nodes can be compared, combined and displayed in a variety of ways. Arithmetic operations can be performed on pairs of corresponding grids to produce resultant grids. Scaling operations can be used to adjust all elements of a grid. Minimum and maximum values can be set for a grid. Values of one grid can be compared to those of another to produce a modified grid based on logical selection criteria of the computer program.

Grids were manipulated in this study principally for the following reasons:

1. To modify the bedrock surface where gridding operations extended it above the topographic surface as a result of the spatial distribution of data.

2. To produce thickness grids by subtracting elevations of a selected lower grid from those of a selected upper grid.

3. To "blank" surfaces in areas within which a surface was not to be extended.

Resource volumes were calculated by summing the products resulting from multiplying grid cell areas by corresponding assigned values of a selected thickness variable.

Display of Control Data and Gridded Values

Gridded variables were displayed on computer plots as contour maps, perspective diagrams and cross-sections. Surface II provided routines for lacing contour lines through a matrix of gridded values, and for producing perspective block diagrams. The third type of display was produced by the CROSEC program which performed cross-sectioning of selected gridded surfaces along user-specified profile lines.

Three computer programs were available for generating posting maps of spatially distributed point data. Generalized Posting Routine (Proudfoot and Lam, 1980) is a "stand alone" system designed specifically to produce posting maps of specified point data. Posting routines integrated with the Terraplot (Terradata, 1981) and Surface II systems were also used. Common to each program is the capability to post values of specified variables ("Z") at corresponding "X" and "Y" data point locations on computer plots. A GSC modified version of the Terraplot posting routine was used for creating most posting maps. The Surface II posting routine was used for posting overlays on other Surface II generated contour maps.

The principal types of computer-generated displays used in this study are listed in Table 5.

TABLE 5

COMPUTER - GENERATED DISPLAYS

POSTINGS OF BOREHOLE "Z" VALUES

GRAPHIC LITHOLOGIC STRIP LOGS

TOPOGRAPHIC CONTOUR MAPS

STRUCTURAL CONTOUR MAPS

SUBCROP LOCATION MAPS

ISOPACH MAPS

ISOLITH MAPS

ISOQUALITY MAPS

CROSS-SECTION PROFILES

PERSPECTIVE BLOCK DIAGRAMS

Topographic Surface

The best available topographic information of the area was digitized. At Sheerness, this information was derived from two sources:

- 1:4,800 scale topographic maps with contours spaced at 1.52 m intervals (provided by Luscar Ltd.)
- 1:50,000 scale National Topographic System (NTS) maps with contours spaced at 7.62 m intervals

The better quality Luscar maps covered the most intensely drilled central portion of the coalfield. After gridding digitized contour information from both series of maps, grid values of the Luscar information were merged with values produced from the NTS information to provide complete topographic representation of the area (Figure 2).

As all borehole data were fundamentally referenced to a depth below surface, it was essential for the development of a reliable geologic model that borehole collar elevations be reliably estimated.

A pseudo-topographic surface grid was generated from the elevations assigned to borehole collars. This grid was compared to the topographic surface grid for the purpose of checking the integrity of assigned borehole collar elevations. A "difference" grid matrix produced by subtracting one grid from the other was contoured and examined for anomalies. Also, a statistical error analysis was performed, using a Surface II routine, to test the integrity of both the topographic grid produced from digitized topographic information and assigned borehole collar elevations. This analysis estimated surface elevations at borehole locations by a process of back-calculating from grid node values established from the digitized topographic surface. In addition to reporting the differences between estimated and assigned values, statistical information regarding the distribution of errors was provided. Significant differences between assigned and estimated values of borehole collar elevations triggered checks of the assigned values and adjustments where necessary.

The mean difference between estimated topographic elevations at the 1228 exploration sites in the database and the assigned borehole collar elevations is -0.03 m, where estimated elevations were back-calculated from a topographic grid having 50 m square cell sizes. The standard deviation about this mean difference is 0.82 m.

The 1:4,800 scale topographic maps provided by Luscar Limited included a location reference grid which was unique to that company. For the purpose of this study, it was necessary to geographically reference locations according to 6° UTM coordinates. It was necessary, therefore, to translate grid data referenced to Luscar coordinates to geographically coincident UTM coordinates. This translation was achieved by a process whereby both UTM and Luscar coordinates were referenced to the nearest Dominion Land Survey (DLS) geodetic survey monuments in the area (referred to as Tap and Colony). The Luscar coordinate system had originally been established using these monuments and was intended to parallel the DLS coordinate system. An error, however, in the DLS survey, manifested by a difference in foresight and backsight supplement azimuths between Tap and Colony of approximately 0.21 degrees, resulted in the Luscar grid being rotated with respect to the DLS grid. Common reference points in both DLS and Luscar coordinates were established, and used to calculate the necessary translation and rotation so that the two grid systems were aligned. After locations were referenced according to DLS coordinates, standard programs, including an inhouse program named LOCATE, were used to convert these values to corresponding UTM coordinates.

Correlation and Data Verification Procedure

Photographic reductions of geophysical logs, in addition to computer-generated graphic strip logs of the coinciding interpreted lithologic units and preliminary correlation information in the database, were produced at 1:600 scale (minilogs). These representations of fundamental geologic data were posted in geographic sequence. The minilogs were initially examined to identify horizons which were correlatable over a sufficiently large number of holes to warrant correlation identification in the database. The posted minilogs afforded the first opportunity to scan geographically organized groups of borehole data in efforts to recognize geologic patterns and data anomalies. All data anomalies were considered to have been the result of potentially erroneous data and, consequently, triggered a verification of data.

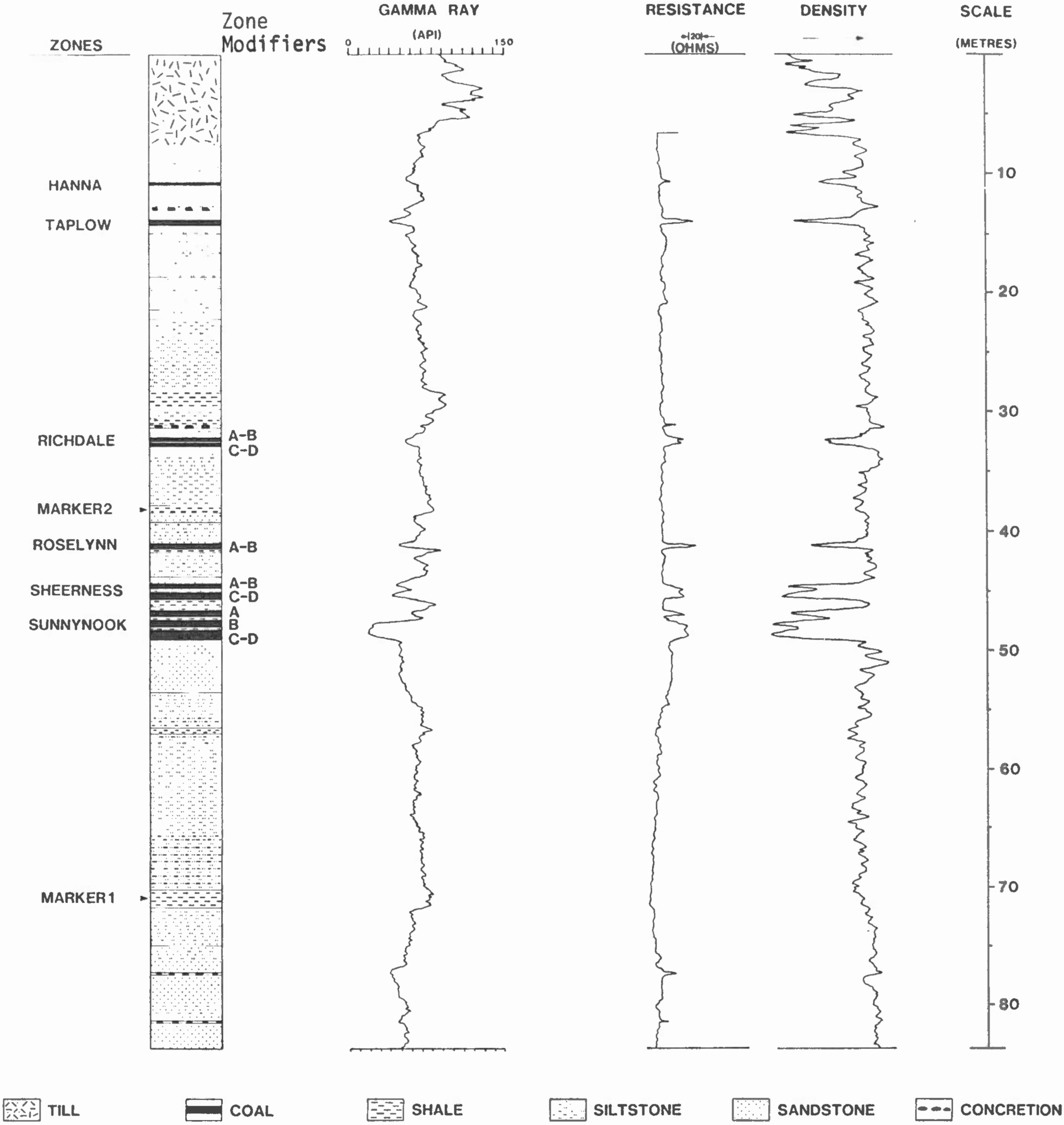
After recognizing all potentially important correlatable lithologic units from the minilogs, data from each of the 1228 borehole locations were examined for the purpose of identifying and labelling correlatable units for subsequent entry to the database. The preliminary correlations made during the initial interpretation of raw data were on a zone-by-zone basis. These interpretations were upgraded to identify beds within zones which were labelled with "zone modifiers", and new information was added. A composite lithologic section of idealized borehole data showing the correlated "zones" and zone modifiers" of the Sheerness Coalfield is provided in Figure 9. This figure shows the maximum stratigraphic section penetrated at Sheerness (85 m) and was produced by combining actual data from three boreholes.

The initial stages of developing a comprehensive correlation framework included attempts to correlate beds which were later found to be either only weakly supported by the data, or lacking in adequate persistency to be of value in evaluating the resource. In subsequent iterations of the correlating process only correlatable units which were reliably supported by the data were included, which resulted in the development of a more meaningful correlation framework.

During the late stages in the development of the correlation framework, "dummy" elevations of correlated surfaces were added to some boreholes in areas where these surfaces had been eroded. The "dummy" elevations were used to control the positions of computer-generated subcrop lines. Some "dummy" elevations were also added to borehole data where correlated surfaces had pinched out or were washed out. These elevations assisted in controlling the positioning of surfaces extrapolated from the real data to locations beyond which they were considered to be absent.

Rigorous data verification procedures were initiated at the completion of each stage of modifications made to the database. The procedures were computer-assisted and usually involved the posting, gridding and contouring of surfaces affected by the modifications.These verification procedures were intended to ensure the development of an error-free database and to check that the data was being effectively honoured by the applied computer processing routines.

The correlation framework was verified by correcting or rationalizing anomalous variations or "bull's eyes" displayed on structural contour and isopach maps. Also, by overlaying postings of penetrated surfaces onto structural contour or isopach maps of those surfaces, it was possible to examine and correct computer extrapolations beyond the limits of data. This procedure was particularly important when establishing the integrity of the positions of subcrop and pinch-out lines of correlated beds. When beds were extrapolated into areas beyond which they had pinched out or were washed out, it was necessary to exercise polygonal control whereby valued grid nodes beyond the actual limits of the surfaces were "blanked".



COMPOSITE LITHOLOGIC SECTION

Figure 9.

GEOLOGY

The verified correlation framework was the basis on which the detailed geologic model of the coalfield was developed. The geologic model was developed in two phases. The first phase considered the present geometries and distributions of coal. The second phase considered depositional environments and mechanisms which controlled the geometries and distributions of the coal, and examined the distribution and geometry of lithologic units in the interseam intervals.

The bedrock surface is entirely covered by till except where exposed along the "badlands" escarpment and in a few other areas of high topographic relief. The till thickness averages 4.8 m. Approximately 1 per cent of the 1228 borehole sites had till intersections greater than 10 m. The contoured bedrock surface is shown in Figure 10. A till isopach map is provided in Figure 11.

Geometries and Distributions of Coal

Within the coal zones delineated in the coalfield, individual beds split, coalesce and pinch out largely as a result of sedimentational events and paleogeographic conditions at the time of peat formation. Postdepositional erosion has truncated all zones at the present bedrock surface and the resulting subcrop lines are shown in Figure 12.

The base of the lowermost coal zone, named Sunnynook, is the most persistent and well defined correlatable surface in the coalfield. Most exploration drilling was terminated after penetrating less than 5 m of floor rock below the zone. The Sunnynook zone lies under less than 20 m of cover in all areas except under the rising topography northwest of the "badlands". The two stratigraphically highest zones identified in the coalfield, named Hanna and Taplow, were insufficiently represented for consideration in this study. These zones are present only in the topographically highest terrain of the northwest corner of the area. The numbers of borehole penetrations used to define each coal zone are shown in Table 6. The distributions of these data are posted on structural contour maps of the base of each of the respective zones (Figures 13 to 16).

All coal seams have been distorted as a result of differential compaction between coal, various interseam sediments and various sediments underlying the coalfield. Allan and Sanderson (1945) mentioned the "troublesome irregularities" in the coal-bearing strata of coal mines in the region which they attributed to differential compaction and lithification. At Sheerness, the major distortions developed after deposition of all four coal zones. Syndepositional topography which affected peat formation was significantly controlled by differential sediment compaction. Various factors which affected the shape and variability of the coal seams are discussed in a following section pertaining to lithostratigraphic relationships and depositional settings.

In central Alberta, beds of all lithotypes occurring near the bedrock surface have been disturbed by overriding glacial movements. Glacially induced bedrock deformation, including folding and faulting of strata, can be seen in roadcut exposures in the plains of central Alberta. Although difficult to analyse from the available borehole data, it is expected that coal zones at Sheerness have been glacially disturbed near subcrop. The nature and extent of this deformation is variable and likely dependent to a large degree on the angle of incidence between bedding planes and bedrock surface. Extrapolation of data from boreholes drilled near subcrop can be misleading if this deformation is not considered.

A brief description of each coal zone follows.

TABLE 6

NUMBERS OF BOREHOLE PENETRATIONS PER COAL ZONE

Coal Zone	Borehole Penetrations	
	Total	% Of All Holes
Hanna*	4	<1
Taplow*	5	<1
Richdale	96	8
Roselynn	313	25
Sheerness	664	54
Sunnynook	1113	91

*Insufficient information for consideration in this study

Sunnynook Coal Zone

The Sunnynook Coal Zone comprises up to four separate seams within a maximum stratigraphic interval of approximately 6 m. It is the lowermost coal zone in the coalfield. This zone contains the thickest and most laterally persistent coal and is, consequently, the most important contributor to resource quantities.

The zone is thinnest (less than 2 m thick) along a northeasterly-trending linear feature which runs diagonally across the north-central part of the coalfield (Figures 13 and 17). Thickening to the northwest is attributable to increasing proportions of rock parting included in the zone. Thickening to the southeast is attributable to increased peat accretion and increased clastic deposition within the zone.

In the southeastern part of the coalfield the Sunnynook zone is represented by three coal horizons termed "A-A", "B-B" and "C-D" according to the identifiers of the contained seams. Rock partings between seams "B" and "C", and "A" and "B" thicken toward the southeast from northeasterly-trending pinch-out lines across the centre of the coalfield (Figures 18 and 19).

In the northwestern part of the coalfield the zone is represented by two coal horizons, "A-A" and "B-D". These horizons coalesce toward the southeast along a northeasterly-trending pinch-out of interseam parting (Figure 19). The "A" seam is absent to the northwest of a line which approximately coincides with the "badlands" feature.

Cross-section A-A' (Figure 20) illustrates the coalescing of coal seams along the northeast trend which bisects the coalfield. Separate splits of seams "C" and "D" were rarely encountered (48 locations) and maximum parting thickness between them was 0.4 m. Data were insufficient for considering these seams separately.

Most of Sunnynook coal is contained within seams "B", "C" and "D". The "A" seam was correlated, even in areas where its contribution to resource quantities was insignificant, because of its potential for providing clues to the depositional settings which led to the termination of Sunnynook peat accretion.

The most noteworthy structural features of the zone were post-depositionally induced and are usually manifested in the shapes of all zones. The following are included among the most significant of these features by virtue of lateral persistency or structural relief:

1. Northeast-trending structural high of 4 to 6 m relief which bisects the coalfield.

2. North-trending compaction or extension fault with 4 to 6 m vertical displacement of strata in the southernmost part of the coalfield.

3. Dome-like structure of about 12 m relief in the west-central part of the coalfield.

These features are highlighted in Figure 13 and are discussed in greater detail in a following section.

Sheerness Coal Zone

The base of the Sheerness Coal Zone is situated from a few centimeters to a maximum of 6 m above the Sunnynook Coal Zone. Although the zone comprises up to four separate seams, termed "A", "B", "C" and "D", there are essentially two coal horizons, "A-B" and "C-D". The seams within each horizon are separated in small areas only by rock partings that are of insufficient thickness and persistency for consideration in this study. These partings were included in samples analysed for coal quality, and consequently they have increased the relative ash contents in these samples with respect to areas where the partings are absent.

The present structure of the Sheerness zone reflects that of the Sunnynook zone (Figure 20). Because of its higher stratigraphic position, however, erosion at the bedrock surface has removed the Sheerness Coal Zone over a larger area, and resulted in a more highly irregular subcrop pattern (Figure 14). The zone averages 0.9 m thick and is second to Sunnynook in contribution to resource quantities. It tends to thicken from northwest to southeast (Figure 21). The rock parting between "A-B" and "C-D" horizons averages 0.1 m thick and generally varies within a narrow range (Figure 22).

In the eastern quarter of the coalfield the Sheerness zone is not present. In this area 8 m to 10 m of sandy lithologies unconformably overlie the Sunnynook zone (Figure 23), which suggests the Sheerness zone may have been removed by postdepositional erosion.

Roselynn Coal Zone

The base of the Roselynn Coal Zone is between 0.5 m and 3.0 m above the top of the Sheerness Coal Zone. The coal is present in one seam, termed "A-B", which has a consistent thickness of approximately 0.4 m and is remarkably persistent where not removed by erosion at the present bedrock surface. It is not an important contributor to resource quantities because of its relatively small areal extent and thickness (Figures 15 and 24).

The similarity of the present structure of the Roselynn zone in the northwestern part of the coalfield to that of Sunnynook and Sheerness zones, indicates that postdepositional deformation uniformly affected all of these zones. In the eastern part of the coalfield, the Roselynn zone diverges somewhat abruptly from the Sheerness zone (Figures 20 and 23). Like the Sheerness zone, it is not present in the easternmost part of the area where the relatively thick sequence of sandy lithologies occupies this stratigraphic position.

Richdale Coal Zone

The Richdale Coal Zone, which is stratigraphically highest of the four delineated coal zones, is present only in the topographically higher parts of the area near the "badlands" in the northwest, and above the sandy lithologies in the east (Figures 16 and 20). It is situated approximately 8.5 m stratigraphically above the Roselynn zone. Although 23 per cent of the 96 boreholes which penetrated the zone encountered two coal horizons, termed "A-B" and "C-D", the distribution of this data did not allow the definition of the shape of the rock parting which separates the horizons. This parting, which consists of siltstone, carbonaceous shale and coaly shale, averages 0.25 m thick where encountered. The zone is considered as a single horizon, termed "A-D", and averages 0.7 m thick (Figure 25). It is not a significant contributor to resource quantities because of its limited areal extent and thickness.

The structure of the Richdale zone is similar to that of the other zones. It is present above the sandy lithologies in the eastern part of the area where Sheerness and Roselynn zones are absent.

Marker Horizons

In addition to the correlation of coal seams, two geologic marker horizons were correlated from borehole data. Both of these marker horizons, termed Marker1 and Marker2, are shaly and silty lithotypes which abruptly overlie much coarser, sandy lithotypes (Figure 9). In each case, the marker horizons form the base of an upward-coarsening sequence of strata. The upward-coarsening succession above Marker1 concluded with the deposition of the sandy sediments upon which Sunnynook peat accreted. The succesion above Marker2 concluded with the deposition of the sandy floor strata of the Richdale Coal Zone.

Attempts early in the study to correlate other marker beds were discontinued when it was determined that those correlations would not enhance the resolution of the geologic model. Correlatable shaly and/or bentonitic beds, including those above the Sunnynook "B" seam and below the Roselynn zone, were not identified as marker horizons in the database because of their close stratigraphic proximity to correlated coal horizons. These lithologic units were used, however, to support the correlations of adjacent coal units.

Marker1

The base of Marker1 is situated at an average of 22 m below the base of the Sunnynook Coal Zone. As most drilling was terminated within 5 m of the base of the Sunnynook zone, only 64 holes penetrated the horizon. The Marker1-Sunnynook interval in all of these holes, which are widespread throughout the field, exhibited a consistent upward-coarsening pattern which provided clues to the genesis of the coalfield. The structure of the base of Marker1 is uncertain because of the scarcity of data (Figure 26).

Marker2

Marker2 is situated between the Roselynn and Richdale coal zones. It is located at an average of 6 m below the base of the Richdale zone and was encountered in 142 boreholes (Figure 27). Although the coarsening-upward above this marker is less pronounced than the sequence above Marker1, it is evident in most sections penetrated and contrasts with the underlying cycles of coarsening and fining-upward which concluded with the deposition of the shaly lithologies of Marker2. Marker2 appears to demarcate two distinct lithofacies.

Lithostratigraphic Relationships

Depositional environments and their control on present seam geometries in the Sheerness Coalfield were interpreted on the basis of observed lithostratigraphic relationships and various geometric domains expressed by the lithologic units within and adjacent to the correlated zones. Lateral and vertical lithologic relationships in stratigraphic intervals between each adjacent pair of correlated surfaces, and within specified distances from correlated surfaces, were examined utilizing procedures outlined by Hughes (1984). Various types of lithologic displays were generated including isopach maps, isolith maps, lithology-percentage maps, ratio maps, cross-sections and perspective block diagrams. In order to recognize the essence of lithologic relationships and to filter incidental depositional responses to the less important geologic events, lithologic units were aggregated into groups according to Table 7. The lateral distributions of these aggregated lithologic groups were examined for preferred orientations and diagnostic depositional patterns, and were compared with appropriate coal distribution maps to detect interrelationships between the distributions of coal and noncoal lithologies. Some stratigraphic intervals were subjected to embedded Markov chain analysis as a statistical means for identifying vertical sequences of lithologic units which may characterize certain depositional environments (Miall, 1973; and Horne et al, 1978). A computer program called MARKOV, based on one written by Doveton (1971), considered upward transitions between lithologic groups and calculated the relative probability of one group succeeding another with respect to the probability resulting from random depositional processes.

The following summary of observed lithostratigraphic relationships for each interval examined precedes a discussion of depositional settings and possible controls on coal distribution interpreted from these observations. Discussions of each stratigraphic interval include descriptions of general shape and lithologic composition of rock splits, and vertical and lateral relationships between gross lithotypes. Although the geometries and distributions of coal and associated rock partings have been briefly discussed in the previous section, observations regarding types and distributions of lithotypes within the partings of each coal zone are described in the following discussion.

TABLE 7

Groupings of lithologic units for Markov analysis and lithofacies modelling

Lithologic Unit	Groupings For Markov Analysis	Groupings For Lithofacies Modelling
Concretion	Lithology 5	Sandstone
Coarse Grained Sandstone	Lithology 1	Sandstone
Medium Grained Sandstone	Lithology 1	Sandstone
Fine Grained Sandstone	Lithology 1	Sandstone
Very Fine Grained	Lithology 1	Sandstone
Silty Sandstone	Lithology 2	Sandstone
Sandy Siltstone	Lithology 2	Siltstone
Siltstone	Lithology 3	Siltstone
Shaly Siltstone	Lithology 3	Siltstone
Silty Shale	Lithology 4	Shale
Shale	Lithology 4	Shale
Bentonitic Shale	Lithology 4	Shale
Bentonite	Lithology 4	Shale
Carbonaceous Shale	Lithology 6	Shale
Coaly Shale	Lithology 6	Shale
Shaly Coal	Lithology 6	Coal
Coal	Lithology 6	Coal
Weathered Coal	Lithology 6	Coal

Interval Below Marker1

Only 54 boreholes penetrated to a depth of 5 m below Marker1. Of these, 29 penetrated to a depth of 10 m below the marker horizon. The 10 m interval which underlies Marker1 is characterized by a well-defined coarsening-upward tendency which concluded with the deposition of relatively coarse-grained and often concretionary sandstones (Figures 28 a and b). The prominence of concretionary units within this interval is unique to the stratigraphic succession studied at Sheerness. Approximately 3 m of silty lithotypes occupy the interval between the top of the coarsest units and the base of the shaly lithologies of Marker1. Insufficient data were available to define lateral distributions of lithotypes in this interval.

Interval Between Marker1 and Sunnynook Coal Zone

The interval between Marker1 and Sunnynook Coal Zone averages 22 m thick. The stratigraphic sequence is characterized by progressive upward-coarsening from the shaly units of Marker1 to the sandy beds which usually formed the base upon which Sunnynook coal was deposited. The results of Markov analysis of all lithologic transitions encountered in boreholes which penetrated this interval demonstrate its strong upward-coarsening tendency (Figure 29). Two coarsening-upward cycles are present at some locations within the interval, each being about 10 m thick.

The distribution of lithologic data in this interval was inadequate to define distinctive lateral facies patterns and relationships. The distribution of aggregated sandy lithotypes to 4 m and 8 m below the Sunnynook zone, along with the associated spatial distributions of available borehole data, are provided in Figures 30 and 31 respectively.

The approximate composition, expressed in terms of percentages of gross lithotypes, for intervals 0-4 m and 4-8 m below the Sunnynook zone respectively are as follows:

	Sandstone	Siltstone	Shale
0-4 m	90	8	2
4-8 m	70	29	1

Sunnynook Coal Zone

The Sunnynook Coal Zone is split between the "A" and "B" seams, and the "B" and "C" seams. The distributions, shapes and compositions of partings provide important clues to the depositional environments associated with the coal formation.

"B-C" Parting

The "B-C" parting splits the Sunnynook "B" and "C" seams in the southeast corner of the coalfield. The parting is wedge-shaped and thickens to the southeast from a northeast-trending pinch-out line (Figures 18 a and b). It attains a maximum thickness of 3.5 m at the extreme southeast corner of the area. The approximate overall lithologic composition of the parting, expressed as percentages of gross lithotypes, is as follows:

Sandstone	Siltstone	Shale
10	45	45

Isolith maps of these gross lithotypes show a marked decrease in thickness of sandy lithotypes from southeast to northwest, toward the pinch-out line of the parting. The sandy lithotypes often do not extend to the pinch-out line, and silty and shaly lithotypes tend to dominate the areas nearest the pinch-out (Figure 32 a, b and c). Although relatively few vertical transitions between lithotypes were penetrated by boreholes, Markov analysis indicates a fining-upward tendency for the interval (Figure 33).

"A-B" Parting

The "A-B" parting, which splits Sunnynook "A" and "B" seams, thickens to the northwest and southeast from the central part of the coalfield (Figures 19 a and b). The parting tends to pinch out in the northeasterly-trending region which bisects the coalfield. In the northwest corner of the area it attains a maximum thickness of 3.0 m. The rate of thickening to the southeast is highest at the extreme limits of borehole data. The approximate overall lithologic composition of the parting, expressed as percentages of gross lithotypes, is as follows:

Sandstone	Siltstone	Shale
7	44	49

The interval is the most shaly of all intervals studied and contains bentonite units over much of the coalfield. Thin bentonite units traced along the face of the Montgomery Mine show the existence of this parting in those areas which show no "A-B" parting on the isopach map. The absence of parting definition in this area results from the unit being too thin (less than 10 cm) to be resolved by geophysical logs or by recognition from borehole cuttings in holes which were not geophysically logged. The presence of these bentonite units is recorded in descriptions of faces of the old mines (Allan, 1936). Isolith maps show the presence of sandstone remote from the pinch-out of the parting and the dominance of finer lithotypes adjacent to the pinch-out lines (Figures 34 a, b and c). There is a progressive increase in the proportion of finer lithotypes from the northwest and southeast toward the pinch-out lines. Markov analysis indicates a fining-upward tendency (Figure 35). In the northwest corner of the area where Sunnynook "A" seam is absent, a stratigraphic succession exists which is laterally equivalent to the succession toward the southeast where the seam pinches out.

Interval Between Sunnynook and Sheerness Coal Zones

The rock split between Sunnynook "A" seam and Sheerness Coal Zone thickens from the southeast side of the coalfield toward the northwest (Figures 36 a and b). The interval thins in the area where coal thicknesses of Sunnynook and Sheerness zones reach maxima. The approximate overall lithologic composition of the interval, expressed as percentages of gross lithotypes, is as follows:

Sandstone	Siltstone	Shale
18	41	41

Sandy lithotypes are not present in the interval in the southeast part of the coalfield near where it pinches out. Silty and shaly lithotypes occupy the stratigraphic interval in this area. Although sandstone and siltstone thicknesses are significant to the northwest, distinctive depositional patterns and relationships are not evident. The distribution of shales, however, shows a distinctive thickening from northwest to southeast, in the direction of overall thinning of the interval. These shales are absent to the extreme northwest of the area (Figures 37 and 38).

The vertical lithologic pattern within the interval where it is thick is generally upward-coarsening from the shaly units which overlie Sunnynook "A" seam, followed by a fining-upward sequence which concluded with deposition of silty units upon which Sheerness coal was deposited. Near the pinch-out the silty and shaly units which occupy the interval exhibit no distinct vertical patterns. Vertical patterns of the noncoal lithologies between the Sunnynook and Sheerness coal zones in areas to the northwest of the pinch-out of Sunnynook "A" seam are similar to those where this seam exists. In the eastern part of the coalfield, this stratigraphic interval is occupied by a succession of relatively coarse, sandy lithologies which overlie the Sunnynook zone.

Sheerness Coal Zone

The Sheerness Coal Zone, which averages 0.9 m thick, has only one significant parting. The parting splits the upper combined "A-B" seams and lower "C-D" seams and, although it is relatively thin, it has sufficient persistency for consideration in interpreting paleoenvironments. Other partings in the zone are thin and cover relatively small areas, and were, therefore, not considered.

"B-C" Parting

The parting which splits the "B" and "C" seams averages 0.1 m thick and is present over most of the coalfield. Although the parting thickness is often less than 0.1 m, the sharply contrasting geophysical responses between parting lithotypes and the enveloping coal often allowed recognition of the parting where it is very thin. The interval is relatively uniform in thickness and does not exhibit distinctive patterns of thickening or thinning (Figure 22).

The approximate overall lithologic composition of the parting, expressed as percentages of gross lithotypes, is as follows:

Sandstone	Siltstone	Shale
1	54	45

The parting is comprised predominantly of siltstone, carbonaceous shale and coaly shale. Neither vertical nor lateral lithologic patterns within the parting intervals are apparent.

Interval Between Sheerness and Roselynn Coal Zones

Proximity to the bedrock surface has resulted in the erosional removal of much of the strata above the Sheerness Coal Zone. Interpretation of depositional environments based on the distribution of lithologic units in these strata is, therefore, progressively more tenuous at higher stratigraphic intervals.

Like the Sheerness Coal Zone, the Roselynn Coal Zone is not present in the easternmost part of the coalfield where sandy lithotypes occupy the equivalent stratigraphic interval. Although the split between Sheerness and Roselynn zones averages 1.7 m thick over most of the coalfield, the thickness exceeds 4 m near the easternmost part of its extent in the east-central part of the coalfield (Figures 20 and 39). The decrease in thickness of the interval from the east and southeast to the west and northwest is somewhat abrupt with the steepest gradients occurring within the most severely eroded area of the central part of the coalfield.

The approximate overall composition of the interval, expressed as percentages of gross lithotypes is as follows:

Sandstone	Siltstone	Shale
29	41	30

No distinctive patterns in the lateral distribution of gross lithotypes are evident within the limited and discontinuous areas where this interval is preserved. Although vertical lithologic relations exhibit both upward-fining and upward-coarsening patterns (Figure 40), the sequence commonly includes carbonaceous shale, shale, and silty shale immediately overlying the Sheerness Coal Zone. These shaly units are usually overlain by coarser silty and sandy units which underlie the characteristic shale and occasional bentonite units which form the Roselynn Coal Zone floor.

Interval Between Roselyn Coal Zone and Marker2

The interval between Roselynn and Richdale coal zones averages 8.5 m thick and is completely represented only in the northwest and east-central part of the coalfield (Figure 41). Two depositional patterns have been recognized within the interval, with Marker2 separating each lithofacies. The interval between the Roselynn Coal Zone and Marker2 averages 2.7 m thick. The interval is present in a small area in the east-central and northwest parts of the coalfield. Based on the limited data available, no consistent patterns of thickening or thinning are evident in this interval (Figure 42).

The approximate overall composition of the interval, expressed as percentages of gross lithotypes, is as follows:

Sandstone	Siltstone	Shale
33	53	14

As can be seen, the interval is composed primarily of lithologies ranging in grain size from silty shale to very fine-grained sandstone.

Lithologic units within the interval do not display any distinctive patterns in their lateral distribution. Vertical lithologic sequences generally include one or more cycles of coarsening- and fining-upward which are overlain by shaly lithologies underlying Marker2 (Figure 43).

Interval Between Marker2 and Richdale Coal Zone

The interval between Marker2 and the Richdale Coal Zone has been eroded over most of the coalfield and is completely represented mainly in the northwest corner of the area (Figure 44). The interval averages 5.9 m thick where completely represented. No distinctive patterns of thickening or thinning of this interval were observed in the small area over which it is present.

The approximate overall composition of the interval, expressed in terms of percentages of gross lithotypes, is as follows:

Sandstone	Siltstone	Shale
39	49	12

The vertical sequences within the interval are characterized by an overall upward-coarsening tendency from the normally shaly units of Marker2 to the sandy lithologies upon which the Richdale Coal Zone was deposited (Figure 45).

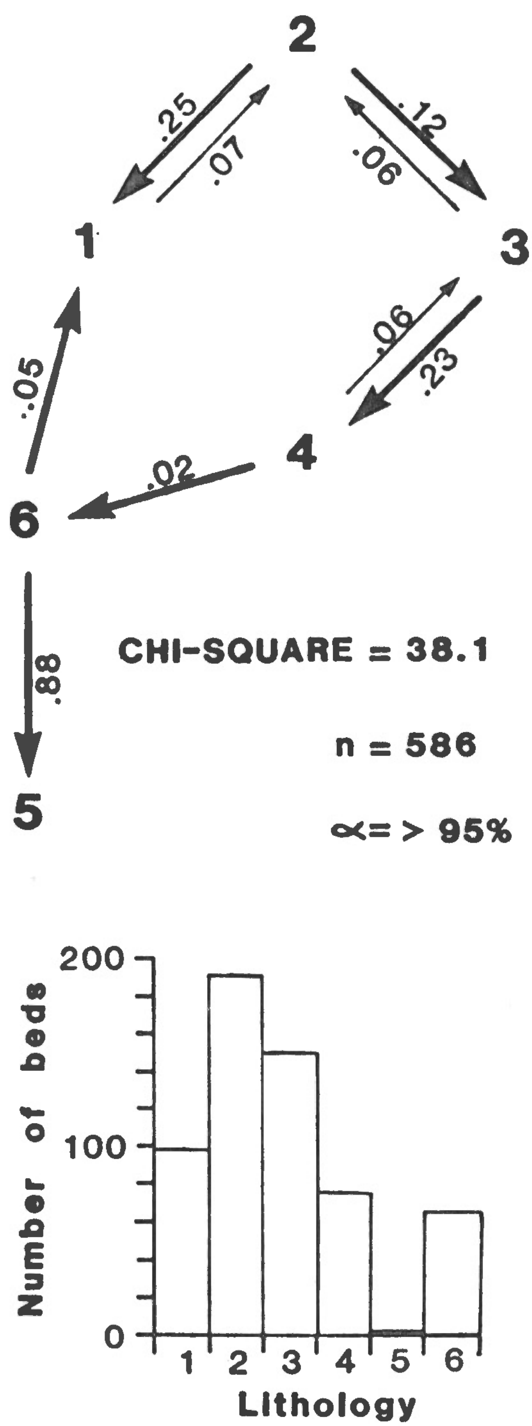


Figure 40.

Markov analysis and lithologic composition of rock split between Sheerness and Roselynn coal zones.

Depositional Settings

Interpretations of depositional environments of the lower Horseshoe Canyon Formation strata within the Sheerness Coalfield were made on the basis of interrelationships between the geometry and distributions of lithologic units. These interpretations were made without the added benefit of various structural, mineralogical and paleontological information commonly used for recognizing depositional environments. Correlative strata in the surface section along the Red Deer River valley near Drumheller have been studied in detail by several previously cited workers. Although strata of the Sheerness Coalfield are younger than correlative strata near Drumheller, similar depositional environments and mechanisms have been recognized. Depositional environments of strata of the Sheerness Coalfield resemble those recognized in the lowermost Horseshoe Canyon Formation of the Dodds-Round Hill Coalfield, 170 km to the northwest (Hughes, 1984).

Several workers, including Shepheard and Hills (1970), Habib (1981), and Hughes (1984), among others, have suggested that the lower Horseshoe Canyon Formation resulted from an eastward-prograding delta complex whereby fluvially supplied clastics were deposited along a north-south trending shoreline of the shallow regressing Bearpaw Sea. Given and Wall (1971) and Habib (op. cit.) described cycles of deltaic deposition of the predominantly marine Bearpaw Formation strata which underlie the Horseshow Canyon Formation in south-central Alberta. They attributed the cyclic nature of deposition to transgressive pulses of the Bearpaw Sea. A transition zone between these marine deposits and the continental deposits of the Horseshoe Canyon Formation was described by Shepheard and Hills (op. cit.) and Wall et al. (1971). Within this transition zone they recognized prodelta and delta front, distributary channel, beach and interdistributary bay, mudflat, open bay and flood plain environments. Hughes (op. cit.) described the coal-bearing succession of the Dodds-Round Hill Coalfield, which includes this transition zone and overlying strata. Within the overall fluvial-deltaic environment, he recognized shallow marine, prodelta, distributary mouth bar, distributary channel, interdistributary bay, beach, fluvial channel, flood plain and swamp-marsh subenvironments. Hughes (op. cit.) described the geometry, and vertical and lateral lithologic relationships that characterized each of these subenvironments.

The stratigraphic succession containing the coal resources at Sheerness displays characteristics of a fluvially-dominated delta, similar to those of the Bearpaw-Horseshoe Canyon transition zone near Drumheller and within the Dodds-Round Hill Coalfield. Several depositional subenvironments similar to those mentioned above have been recognized in the strata of the Sheerness Coalfield.

Interval Below Sunnynook Coal Zone

The coarsening-upward succession of strata below Marker1 represents a regressive phase following one of the last episodic transgressive pulses which occurred during deposition of the Bearpaw Formation. Only the upper part of the cycle, which concluded with the deposition of relatively coarse, sandy lithotypes, including concretionary sandstone, is represented in most Sheerness boreholes. The coarsening-upward pattern reflects, prograding deposition from a distributary system in areas progressively more proximal to the mouth. Hughes (1984) suggested that concretionary units might signal horizons which were subaerially exposed. The sands deposited at the end of the cycle might represent distributary mouth bar deposits, or possibly beach deposits.. Data were insufficient for defining geometry and distribution of lithotypes in support of a more reliable interpretation of depositional processes.

The finer grained lithotypes which overlie this upward-coarsening cycle and which underlie Marker1 are considered to have been deposited during a period of marine transgression. The vertical lithologic transition sequence conforms to those described by Habib (1981) for constructional and destructional phases of delta evolution within the upper Bearpaw Formation. Progradation followed by avulsion, compaction and subsidence is the suggested sequence of geologic events which affected constructional and destructional cycles within the delta complex.

The predominantly shaly lithotypes of Marker1 form the basal beds of an upward-coarsening sequence which is overlain by the subaerial swamp-marsh facies which underlie the Sunnynook Coal Zone. Marker1 represents the initial deposition within a progradational sequence of progressively increasing energy. The increasing energy was in response to progressively shallower marine conditions within the receiving basin resulting from the progradation of a major distributary into the area. It is a typical fluvially-dominated deltaic complex (Horne, 1978). The widespread distribution of sandstones in the uppermost 4 m of the succession suggests high energy sedimentation characteristic of distributary mouth bar deposits of the upper delta front. These sediments constitute the last stage in a depositional sequence which began with the fine-grained shallow marine lithotype at the base of the delta front, and concluded with coarse fractions of the proximal distributary mouth bar and channel deposits.

The laterally extensive sandstone facies between 0 and 8 m below the base of the Sunnynook Coal Zone does not exhibit linear sedimentary features common to distributary mouth bar and channel subenvironments (Figures 30 and 31). The lack of borehole data to and below 8 m from the base of the Sunnynook Coal Zone precludes a comprehensive interpretation of geologic events for this part of the stratigraphic section. A distinctive linear northeasterly-trending structural feature exhibited in the coal horizons (Figure 13), however, may have been controlled by an underlying linear distributary mouth bar deposit. The coarsest sandy lithotypes at the top of the upward-coarsening cycle often very abruptly overlie finer-grained lithologies which might indicate basal scouring common to distributary mouth bar deposition proximal to a distributary mouth. In some areas a secondary upward-coarsening cycle occurs near the top of the interval. This cycle may represent a period of reduced flow, possibly resulting from avulsion, followed by a period of rejuvenated flow.

Post-depositional deformation of the stratigraphic succession within the coalfield affected the general shapes of all coal zones relatively uniformly. This deformation is attributed primarily to differential diagenetic compaction of strata below the Sunnynook Coal Zone. In addition to postdepositional deformation, differential compaction of these strata probably had syndepositional affects on the landscape upon which the paludal subenvironments formed to host coal precursors.

Sunnynook Coal Zone

The sandstone units at the top of the overall upward-coarsening sequence above Marker1 are the basal beds of the Sunnynook Coal Zone. These beds became subaerially exposed in environmental conditions favourable to peat accretion. These environmental conditions apparently extended over the entire area of the coalfield as suggested by the persistency of Sunnynook coal. The subaerial exposure resulted from a reduced rate of subsidence in the area with respect to other areas in the regressive marine setting. Higher topography resulting from sedimentation might have resulted in avulsion of major distributaries in the area in favour of adjacent lower lying areas.

The Sunnynook Coal Zone represents a relatively stable period of the delta plain. Peat accretion was occasionally interrupted by overbank flooding of distributaries adjacent to the coalfield. The first significant interruption to peat growth resulted from the deposition of the "B-C" parting. The wedge-like shape of this parting, which thickens to the southeast, suggests that the source of detritus was in that direction (Figures 18 a and b). The proportional increase of the finer-grained lithotypes toward the northeasterly-trending pinch-out of the parting indicates a progressive decrease in sediment transport energy with distance from the source of detritus. This is characteristic of overbank and crevasse splay deposits. The northeasterly-trending pinch-out line probably demarcates a topographic high above which floodwaters did not reach.

Peat growth resumed after deposition of the "B-C" parting and continued until a second period of clastic influx caused another interruption, resulting in the deposition of the "A-B" parting. This parting wedges outward toward the northwest and southeast (Figures 19 a and b), The progressive coarsening of lithotypes in these directions suggests deposition resulting from overbank or crevasse splay flooding from both southeast and northwest of the coalfield. The parting is comprised of a high proportion of shaly lithotypes, with significant coarser lithotypes only in areas quite remote from the central northeasterly-trending region where the parting thins and in places pinches out. The predominance of these shaly units over a large central portion of the coalfield indicates a low energy environment characteristic of an interdistributary floodplain where deposition occurred in essentially standing or very slowly moving bodies of water.

The bentonite and associated shaly units within the parting in areas where it is thinnest are probably alteration products of volcanic ash falls. The bentonite units examined in the Montgomery Mine generally appear relatively uncontaminated by extraneous detritus. This suggests the in situ alteration and preservation of these ash beds. It has been suggested that an aqueous environment is favourable for the alteration of ash to bentonite (Grim and Guven, 1978). Standing bodies of water on the floodplain would have provided the very low energy, aqueous conditions appropriate to in situ preservation and alteration of the ash.

The northeasterly-trending region which bisects the coalfield, where the parting is thinnest, may represent a syndepositional topographic high. Although this area might not have escaped occasional inundation, extremely low sediment transport energies in this part of the floodplain resulted in the deposition of only the finest of suspended solids.

A relatively short period when paludal conditions suitable for peat accretion prevailed in the interdistributary floodplain occurred shortly after accretion of the Sunnynook "B" seam terminated. Deposition of the relatively thin parting between Sunnynook "A" and "B" over most of the coalfield occurred during this period. The seam was not deposited in the northwest corner of the coalfield because of a lack of suitable conditions in that area. This may be attributable to the presence of a major distributary to the northwest, with associated higher sedimentation rates, which would be less favorable for coal accumulation.

Sunnynook to Sheerness Coal Zones

Another influx of clastic sediments into the paludal environment terminated the relatively short accretion period of Sunnynook "A" coal. Sediment was deposited over the peat to form the wedge-shaped rock split between Sunnynook and Sheerness zones. This parting, which thickens progressively to the northwest from the southeast side of the coalfield, resulted from overbank or crevasse splay deposition originating northwest of the coalfield (Figures 36 a and b). The Sheerness zone tends to coalesce with the Sunnynook zone in the area of the previously discussed syndepositional topographic high. The increase of finer-grained lithotypes toward the pinch-out, and the vertical lithologic transition patterns, suggest deposition within a floodplain environment. The geometry of the split and lithologic relationships within it are similar to those of the Sunnynook "A-B" parting.

The total interval between the Sunnynook "B" bed and the base of the Sheerness zone is considered to have been deposited in an interdistributary floodplain. Most clastics were transported from a distributary located northwest of the coalfield. Some influx, however, originated from areas southeast of the coalfield. There was a brief interlude when suitable conditions for peat accumulation existed over most of the floodplain which resulted in the deposition of Sunnynook "A" coal. Very low energy depositional environments which existed prior to, and following the peat deposition, particularly in the topographically higher areas of the central part of the floodplain, were favourable to the deposition, alteration and preservation of volcanic ash which fell onto the plain. Ash which altered to bentonite in wet conditions was not significantly reworked by sedimentological processes. Aggregate bentonite thicknesses near the roof and floor of Sunnynook "A" coal are displayed in the postings of Figure 46.

Sheerness Coal Zone

Relatively stable paludal conditions developed on the floodplain which resulted in the peat accretion of the Sheerness Coal Zone. The area was removed from the effects of overbank flooding during this period suggesting active distributaries were distant from the coalfield. The thin layer of predominantly siltstone, carbonaceous shale and coaly shale which constitute the Sheerness "B-C" parting probably resulted from overbank flooding of a remote distributary. This uniformly thin layer of sediment was deposited over the floodplain except in the area of the previously discussed topographically higher terrain where this parting tends to be absent (Figure 22).

The syndepositional landscape is considered to have been relatively featureless during this period of peat accretion, with the exception of a topographically higher area in the east-central part of the coalfield.

Sheerness to Roselynn Coal Zones

The deposition of Sheerness coal precursors was terminated by an influx of shaly and silty sediments onto the floodplain. Although the overall shape of the rock split between Sheerness and Roselynn zones is uncertain because of glacial erosion, the sharp increase in thickness from a mean of approximately 1.2 m in the northwest to about 4.0 m in the southeast is noteworthy (Figures 20 and 39). The split may have an overall wedge shape which opens sharply to the east and, although converging to the west and northwest, never pinches out within the coalfield. Only two geophysically logged boreholes were drilled in the eastern part of the area where the interval is thickest. One of these boreholes penetrated a relatively thick sequence of sandy lithotypes, within which neither Sheerness nor Roselynn coal zones are present. The other borehole, located approximately 1 km to the northwest, penetrated the Sheerness Coal Zone and an overlying 6 m thick sequence of relatively coarse-grained lithologies within which the Roselynn Coal Zone is absent.

The depositional scenario for the split was apparently dominated, in the eastern part of the area, by a distributary channel which resulted in the erosion of the Sheerness zone and in-channel deposition of relatively coarse sandy sediment. The orientation of the distributary channel is uncertain, but it probably trended approximately north-northeast as other orientations would have been evident in a greater number of boreholes. The Roselynn coal seam did not develop in the channel area. In adjacent areas to the west of the channel, a relatively thick sequence of alternatively coarsening- and fining-upward silty and sandy sediments was deposited by overbank flooding or crevasse splay processes. A linear structural high in the Sheerness zone which trends northeasterly across the north-central part of the coalfield (Figure 13), may have created a syndepositional topographic high which was responsible for the relatively sharp thinning of this interval to the northwest.

Roselynn Coal Zone

The persistency and uniform thickness of the Roselynn Coal Zone indicated deposition within a relatively stable and topographically featureless environment. It is suggested that deposition above the Sheerness zone from the nearby distributary, filled topographic irregularities. The fine-grained shaly lithotypes which usually form the floor of the Roselynn zone often overlie a thin fining-upward sequence. The presence of shale is sufficiently uniform to be considered a marker horizon. It represents very low energy conditions just prior to the emergence of paludal environments associated with the Roselynn Coal Zone.

A depositional scenario is proposed whereby minor subsidence of the area followed avulsion and lateral migration of the nearby distributary channel away from the area. An interdistributary bay environment resulted. Clastic supply to this low energy aqueous environment came from areas remote from the coalfield. Following the deposition of muddy sediment and volcanic ash, the entire area developed into a peat accreting paludal environment.

Roselynn to Richdale Coal Zones

The termination of Roselynn peat accretion and subsequent deposition is characterized by alternating coarsening- and fining-upward sequences which concluded with the deposition of shaly lithotypes which constitute Marker2. The depositional environment for this succession is interpreted as a return to interdistributary bay conditions. Variable sediment transport energies reflected by the vertical lithologic sequences suggests proximity to clastic supplying distributaries. Ultimately, the shaly units of Marker2 were deposited in very low energy environments or in standing water.

Deposition above Marker2 is characterized by upward-coarsening sequences which concluded with the deposition of sandy lithotypes that underlie the Richdale Coal Zone. The stratigraphic sequence between Marker2 and the Richdale zone is composed of predominantly silty and sandy lithotypes. The interval contains the highest proportion of sandy lithotypes in the succession, with the exception of those deposited during the constructional deltaic processes below the Sunnynook zone. The succession above Marker2 is considered to have been deposited as a constructional bay-fill sequence, as the upward-coarsening lithologic sequences are characteristic of a small-scale delta. Eventual subaerial exposure resulted in the establishment of peat accreting paludal environments of the Richdale zone.

Richdale Coal Zone

Insufficient representations of the Richdale Coal Zone and overlying strata are available in the coalfield to consider their depositional environments.

Summarized Description of the Depositional Model

The Sheerness Coalfield is comprised of strata deposited on the lower delta plain of a northeasterly-prograding delta complex. Various depositional subenvironments have been recognized within this deltaic complex. The coal-bearing succession overlies a coarsening-upward stratigraphic sequence typically developed by prograding distributary mouth bar deposition over prodelta shales. Subaerial exposure of the lower delta plain resulted in paludal conditions which were often favourable to peat accretion. Peat accretion was interrupted at various times by drowning and burial beneath non-coal clastics.

The Sunnynook and Sheerness coal zones developed in the paludal conditions of an interdistributary floodplain. Influx of clastics into the swamp-marsh subenvironment resulted from overbank or crevasse splay flooding from distributaries located to the northwest and southeast of the coalfield. These clastics were deposited as wedge-shaped partings between peat horizons.

A distributary channel in the eastern part of the area eroded the underlying Sheerness Coal Zone and prevented the lateral continuation of the Roselynn Coal Zone. Overbank or crevasse splay clastics supplied from this distributary buried the adjacent Sheerness coal precursors. Sandy sediments were unconformably deposited as active channel fill.

A shallow interdistributary bay environment developed prior to the formation of the Roselynn Coal Zone. This coal zone was deposited on topographically flat, shaly, bay-fill deposits. After accretion of a relatively uniform layer of peat, the Roselynn coal zone was drowned and buried by clastic sediments which marked the return of interdistributary bay conditions.

A period of deposition within a variable energy environment prevailed in the interdistributary bay until the shaly clastics of Marker2 were deposited. This period probably represents a time of increasing water depth within the bay. This "destructional" phase was followed by a "constructional" period of deposition above Marker2 when water depths became increasingly shallower and depositional energies higher. Ultimately, the Richdale Coal Zone was established on these interdistributary bay deposits.

Paleoflow direction during the deposition of coal-bearing strata of the Sheerness Coalfield was predominantly toward the northeast. Partings within coal zones, and splits between coal zones are usually wedge shaped and open to the northwest and/or southeast, directions which may have been essentially perpendicular to paleoflow (Figure 20). Uniform thicknesses of partings and rock splits are seen in profiles which run parallel to paleoflow directions (Figures 47 and 48), whereas wedge-shaped geometries are evident in the profile perpendicular to paleoflow.

The thickest accumulations of peat were deposited autochthonously in those areas where growth was least affected by overbank or crevasse splay sedimentation. These areas may have been syndepositional topographic highs or may have been distant from distributaries, and therefore less susceptible to flooding.

Although sedimentation resulting from flood events was the major depositional mechanism of non-coal strata during accretion of the coal-bearing succession, volcanic ash was also deposited onto the coalfield. This ash was altered to bentonite, possibly in wet conditions, and was preserved in situ in the very low energy environments which were most remote from the effects of flooding.

The most predominant syndepositional topographic high during the accretion of Sunnynook and Sheerness coal precursors was the northeasterly-trending area which bisects the coalfield. Within this area partings thin, coal thicknesses tend to be greatest and preserved bentonite occurrences tend to be most prolific. Prior to the accretion of Roselynn coal precursors, a paleotopographic high, coincidental to a current structural high which trends northeasterly across the north-central part of the coalfield, emerged to control sediment thicknesses which resulted from overbank flooding of a channel which flowed north-northeasterly across the easternmost part of the coalfield.

Paleotopography was most profoundly affected by differential rates of subsidence of the coalfield caused by differential diagenetic compaction of the underlying strata. Topographic highs were probably controlled by the presence and shape of the coarsest, most proximal distributary mouth bar deposits below the Sunnynook Coal Zone upon which the coal-bearing strata were deposited. The northerly-trending structural lineament of abrupt vertical displacement of strata in the southern part of the coalfield is probably a compaction or extension fault.

The proposed depositional model is similar to that described by Hughes (1984) for the Dodds-Round Hill Coalfield. With the exception of a poorly defined in-channel sequence in the eastern part of the Sheerness Coalfield, channel deposits are not apparent. There is no evidence of point bar deposition within the stratigraphic succession. Although beach deposits have not been identified, it is conceivable that the apparently tabular sands which form the floor of Sunnynook coal might have been reworked in a beach subenvironment.

COAL RESOURCES

The term "coal resources" has been defined as the coal that is contained in seams occurring within specified limits of thickness and depth from surface (Bielenstein et al., 1979). Irvine (1981) described the resource classification scheme that was adapted for this study. The resource potential of the Sheerness Coalfield was determined using the geologic model established from available borehole data. Resource quantities were estimated and categorized with respect to relative exploitation potential and assurance of existence, according to specified parameters. "Resources of immediate interest" are considered to have the higher potential for exploitation in the foreseeable future, whereas, "resources of future interest" are resources for possible exploitation consideration at some time in the future. Assessments of the relative degrees of certainty of the existence of estimated resource quantities have been made on the basis of spatial distribution of data. Resources were subdivided according to distance from nearest control point into "measured", "indicated" and "inferred" categories.

This study does not consider factors pertaining specifically to either economic viability or "recoverable reserves". Incremental resource quantities are provided, however, for various depths of overburden and, in some cases, for various ratios of overburden quantities to in situ coal tonnages. These depth and ratio attributes have fundamental economic implications.

The distributions of coal quality attributes within the resource were examined using available analytical data.

Applied Methods and Parameters

The resources of each coal zone were evaluated separately. The procedure used was based on the assignment of a single net coal thickness value for each borehole intersection of each coal zone. The assigned thickness value is the aggregate thickness of discrete coal seams within the zone which meet specified qualification criteria. For this study, discrete coal seams which exceeded 0.6 m thick, after including rock partings which were less than 0.15 m thick as coal, qualified for aggregation in the net coal thickness. That is, seams less than or equal to 0.6 m thick, which were separated from adjacent seams by 0.15 m or more parting, were excluded from the estimated resource quantities. The calculation of net coal thickness for each borehole was performed by the computer program named "TOTAL". In addition to computing net coal thickness values, TOTAL provides information on the considered borehole intersections, such as whether a coal zone was present but too thin, eroded, not deposited or not penetrated, and coal and rock thickness portions of total coal, plus coal and rock thicknesses excluded from the summation.

A grid of net coal thickness values was generated for each coal zone by extrapolating and interpolating borehole values according to previously described procedures. For each coal zone, the grid of net coal thickness was "blanked" according to the structural contour grid of the base of the zone in order to ensure that previously established subcrop positions and other grid extrapolation controls were properly honoured. The net coal thickness grid was then added to this elevation grid to produce a grid of "pseudo-top" elevations of the coal zone. These elevations were subtracted from corresponding topographic elevations to provide an overburden thickness grid for the zone.

The "DMAP" routine of the Surface II system was used to generate grid values of distances between grid nodes and net coal thickness control data.

A computer program named "TONS" was used to calculate incremental resource quantities of each coal zone according to specified increments of depth of overburden, coal thickness and distance from borehole control. The computation was performed using grids of the net coal thickness, overburden depth, and distance from control variables. Parameters used to calculate resource quantities, and to categorize them according to relative exploitation potential and assurance of existence, are shown in Table 8. The program provides both detailed and summarized reports of "resources of immediate interest" and "resources of future interest", classified according to "measured", "indicated", and "inferred" categories (Appendix).

In addition to estimating coal resource tonnages as a function of depth below surface, resources of the Sunnynook Coal Zone, which comprise in excess of 90 per cent of the total resource, were categorized according to the ratio of overburden volume to coal tonnage. The gridded net coal thickness values were scaled by a specific gravity factor of 1.35 to produce a corresponding net coal "tonnage" grid. The "overburden depth" grid was divided by the "net coal tonnage" grid to produce a ratio grid. This ratio grid was used by the program "TONS" instead of the previously used overburden depth grid, to calculate incremental resource quantities as a function of this ratio.

The methods and parameters applied to the study of coal quality are discussed in a following section.

Resource Quantities

Contour maps showing net coal thickness, depth from surface and distance from control data are provided for each of the coal zones (Figures 49 to 52). A ratio map of overburden volume to coal tonnage is provided for the Sunnynook Coal Zone (Figure 49d). A contour map of the aggregated thicknesses of net coal of all zones is provided in Figure 53a. A profile of net coal thicknesses along a northwest trending line across the centre of the coalfield is provided in Figure 53b. A contour map of aggregate overburden thickness of all coal zones and a profile showing variation in thickness are provided in Figures 54a and 54b.

A summary of all estimated coal resources is provided in Table 9. Summaries of resources of immediate and future interest, subdivided by coal zone, are tabulated in Tables 10 to 12 respectively. Summaries of resources of immediate interest, and the incremental distributions of these resources for each coal zone are provided in Tables 13 to 16. Table 17 summarizes the resources of future interest of the Sunnynook zone by incremental overburden to coal ratios. The economic implications regarding this portion of the resource are implicit. Full details of all resource estimates are provided in the appendix.

Various charts are provided which graphically display incremental and cumulative resource quantities by assigned categories of relative exploitation potential and assurance of existence (Figures 55 to 61).

COAL RESOURCE CLASSIFICATION SCHEME

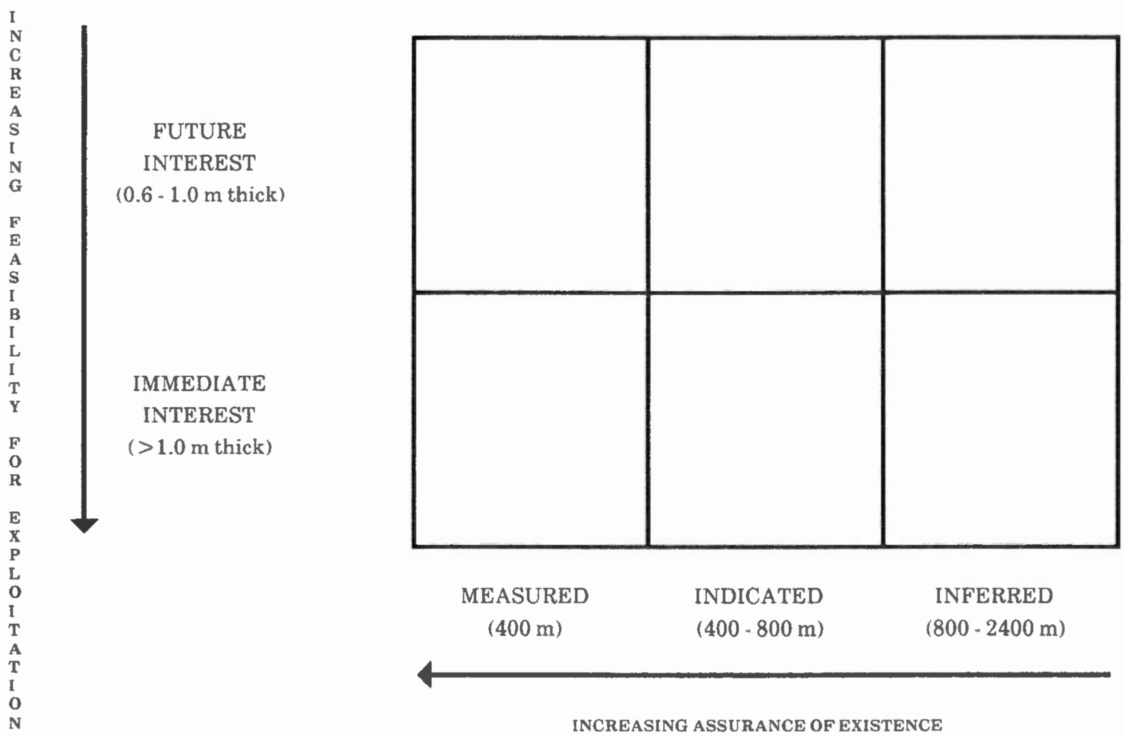


TABLE 8

Parameters used for estimating and classifying coal resources

Minimum acceptable coal bed thickness	0.60 m
Maximum parting thickness considered as coal	0.15 m
RESOURCES OF IMMEDIATE INTEREST	
Minimum coal thickness	1.0 m
Maximum depth	50.0 m
RESOURCES OF FUTURE INTEREST	
Minimum coal thickness	0.6 m
Maximum depth	100.0 m
ASSURANCE OF EXISTENCE	
Maximum distance from control data	
Measured	400 m
Indicated	800 m
Inferred	2400 m
IN SITU BULK SPECIFIC GRAVITY	1.35

TABLE 9

Summary of estimated coal resources

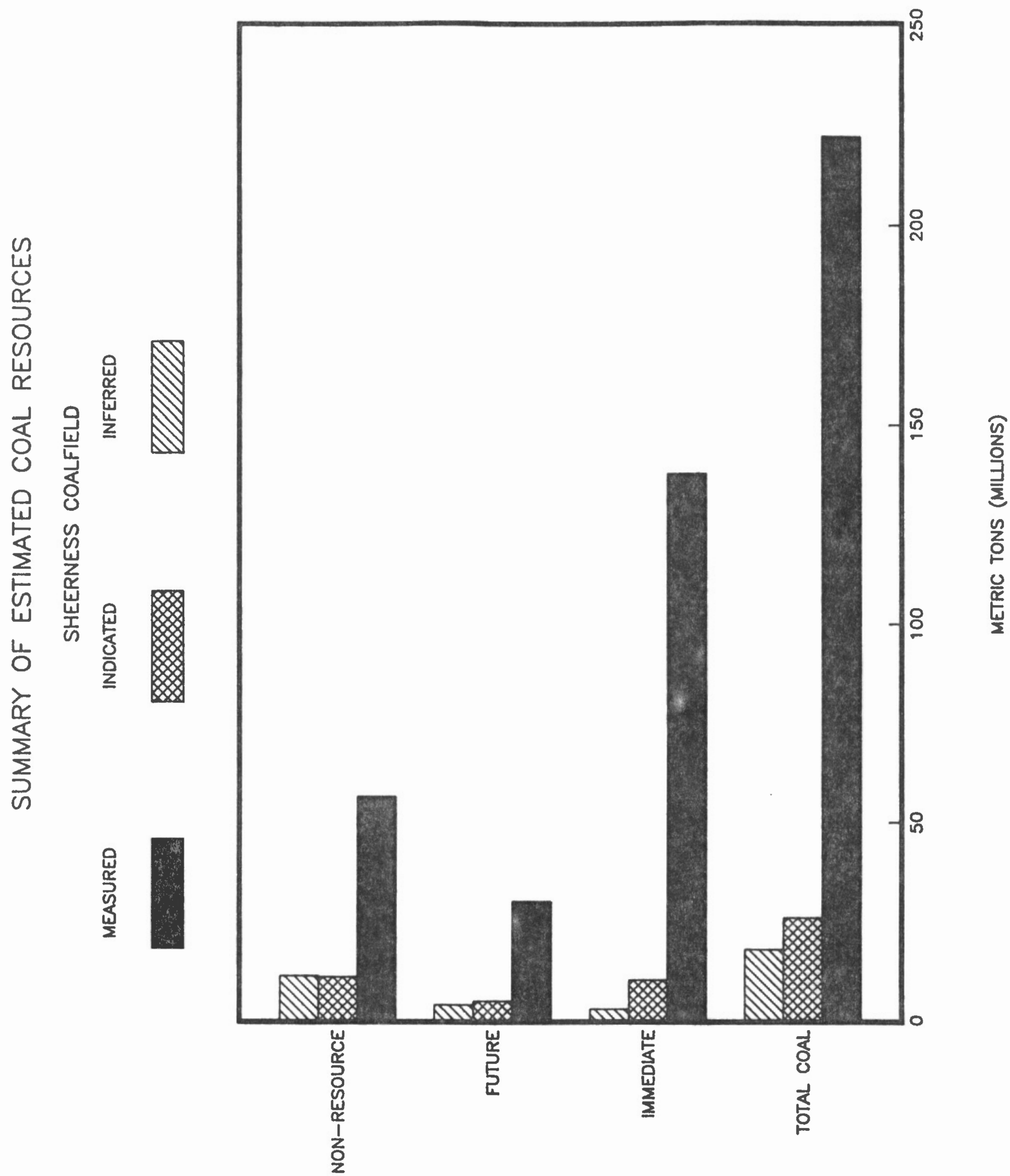
(million metric tons)

	Measured	Indicated	Inferred
Total Coal *			
>1.0 m aggregate thickness	166.645	13.740	6.530
<1.0 m aggregate thickness	55.720	12.115	11.270
Totals	222.365	25.855	17.800
Resource Coal -			
Immediate Interest	137.840	10.155	2.755
Future Interest	29.880	4.770	3.855
Totals	167.720	14.925	6.610
Non-Resource Coal **	54.645	10.930	11.190

* No minimum seam thickness restriction applied to resource quantities

** Total coal minus resource coal.

N.B. All coal occurs within a depth of 60 m from surface.



SUMMARY OF ESTIMATED COAL RESOURCES
SHEERNESS COALFIELD
MEASURED
INDICATED
INFERRED
NON-RESOURCE
FUTURE
IMMEDIATE
TOTAL COAL
0
50
100
150
200
250
METRIC TONS (MILLIONS)

Figure 55.

TABLE 10

Summary of resources of immediate interest

(million metric tons)

Coal Zone	Measured	Indicated	Inferred
Sunnynook Zone	136.015	9.520	2.625
Sheerness Zone	6.785	0.635	0.030
Roselynn Zone	-	-	-
Richdale Zone	0.540	-	-
Sub-totals	143.340	10.155	2.755
Less: mined-to-date	5.500	-	-
Totals	137.840	10.155	2.755

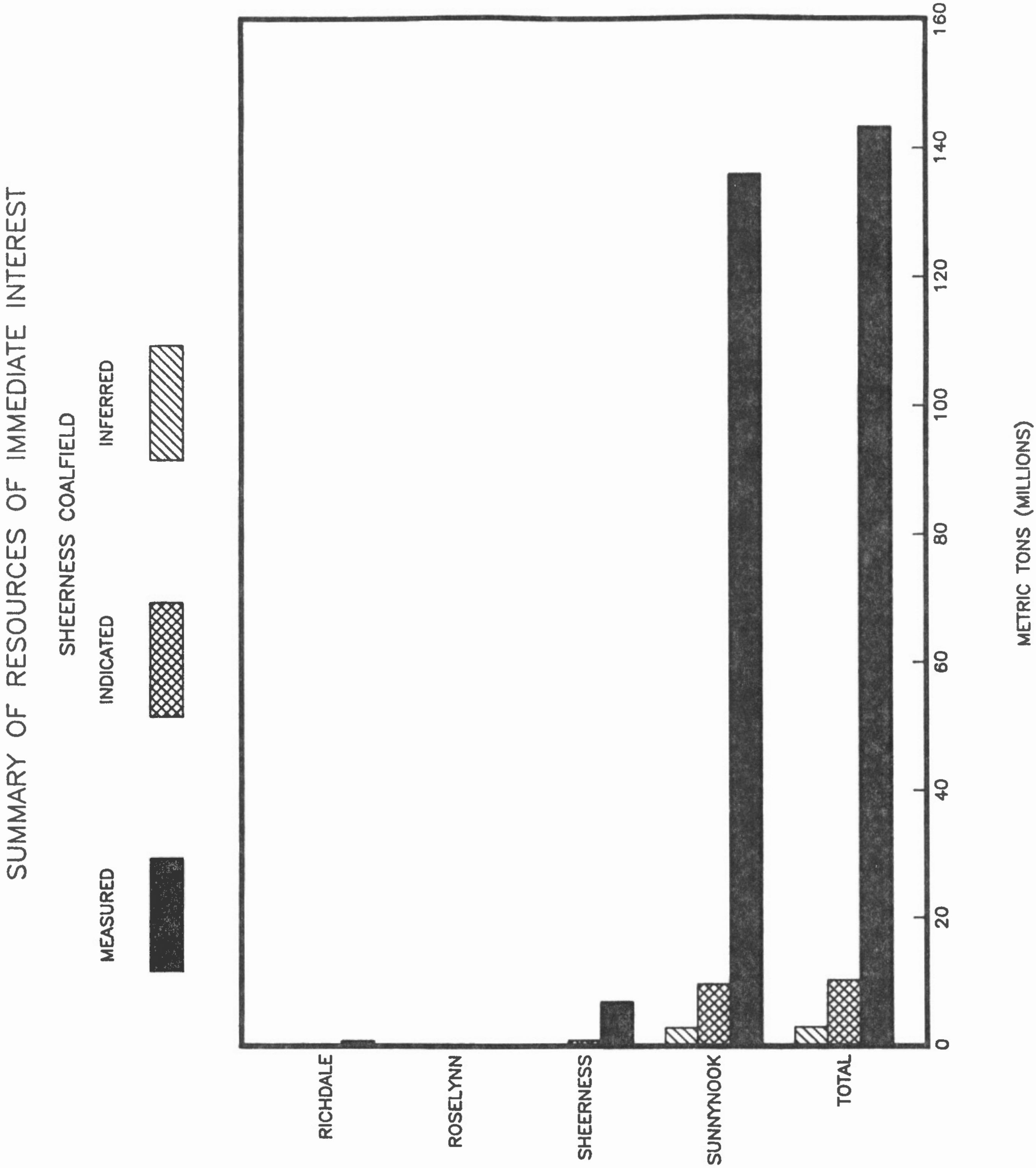

SUMMARY OF RESOURCES OF IMMEDIATE INTEREST
SHEERNESS COALFIELD
MEASURED
INDICATED
INFERRED
RICHDALE
ROSELYNN
SHEERNESS
SUNNYNOOK
TOTAL
0
20
40
60
80
100
120
140
160
METRIC TONS (MILLIONS)

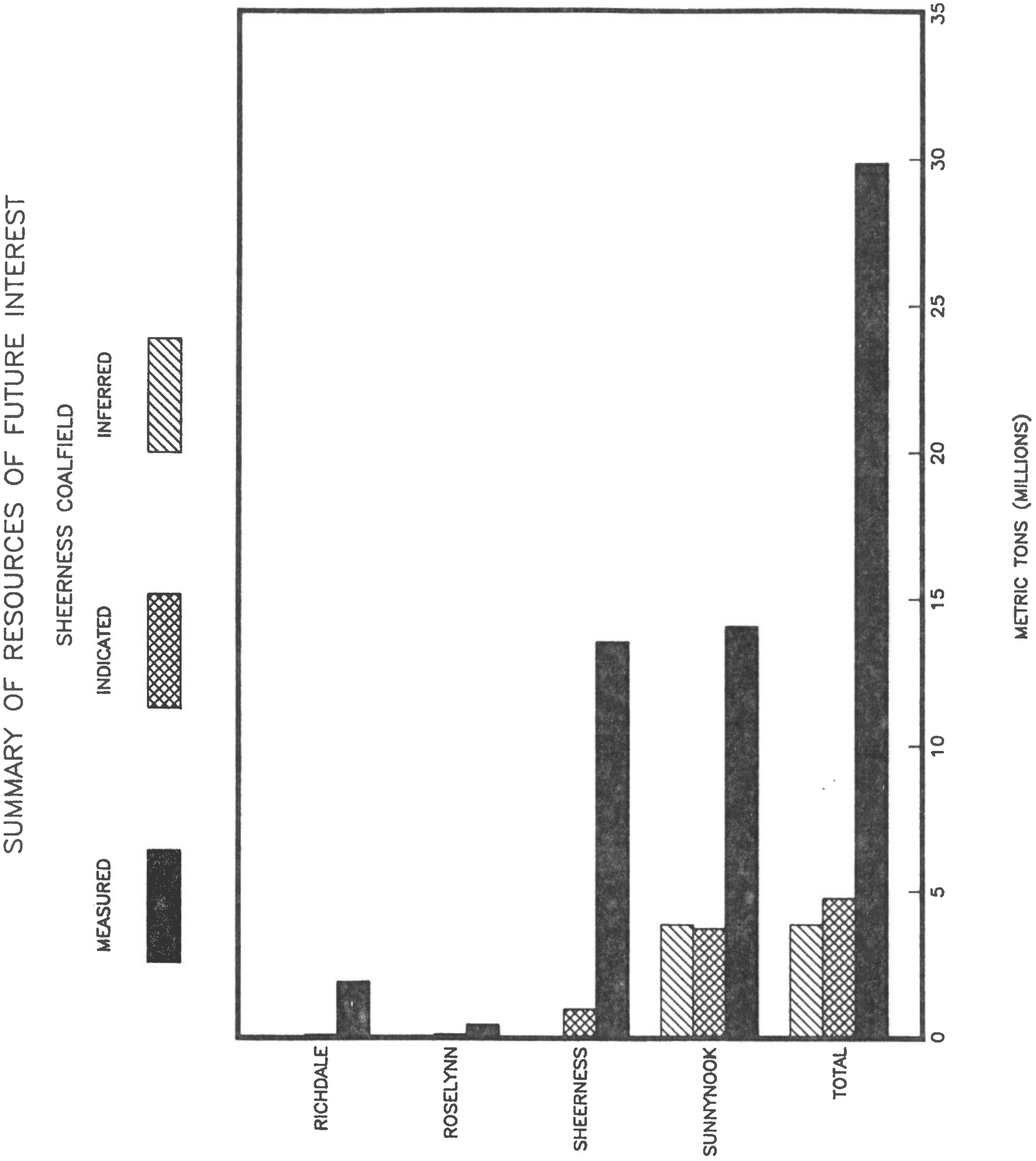
Figure 56.

TABLE 11

Summary of resources of future interest

(million metric tons)

Coal Zone	Measured	Indicated	Inferred
Sunnynook Zone	14.065	3.720	3.855
Sheerness Zone	13.535	0.945	-
Roselynn Zone	0.405	0.060	-
Richdale Zone	1.875	0.045	-
Totals	29.880	4.770	3.855



SUMMARY OF RESOURCES OF FUTURE INTEREST
SHEERNESS COALFIELD
MEASURED
INDICATED
INFERRED
RICHDALE
ROSELYNN
SHEERNESS
SUNNYNOOK
TOTAL
0
5
10
15
20
25
30
35
METRIC TONS (MILLIONS)

Figure 57.

TABLE 12

Measured resources of immediate interest by incremental overburden depths

Depth From Surface (m)	Sunnynook	Sheerness (million metric tons)	Richdale	Cumulative Total
0 - 5	31.455	2.275	0.465	34.195
5 - 10	63.260	3.810	0.060	101.325
10 - 15	28.470	0.640	0.015	130.450
15 - 20	10.735	0.060	-	141.245
20 - 25	1.125	-	-	142.370
25 - 30	0.340	-	-	142.710
30 - 35	0.210	-	-	142.920
35 - 40	0.295	-	-	143.215
40 - 45	0.110	-	-	143.325
45 - 50	0.015	-	-	143.340
Sub-totals	136.015	6.785	0.540	143.340
			Less: mined-to-date	5.500
			Total measured resources	137.840

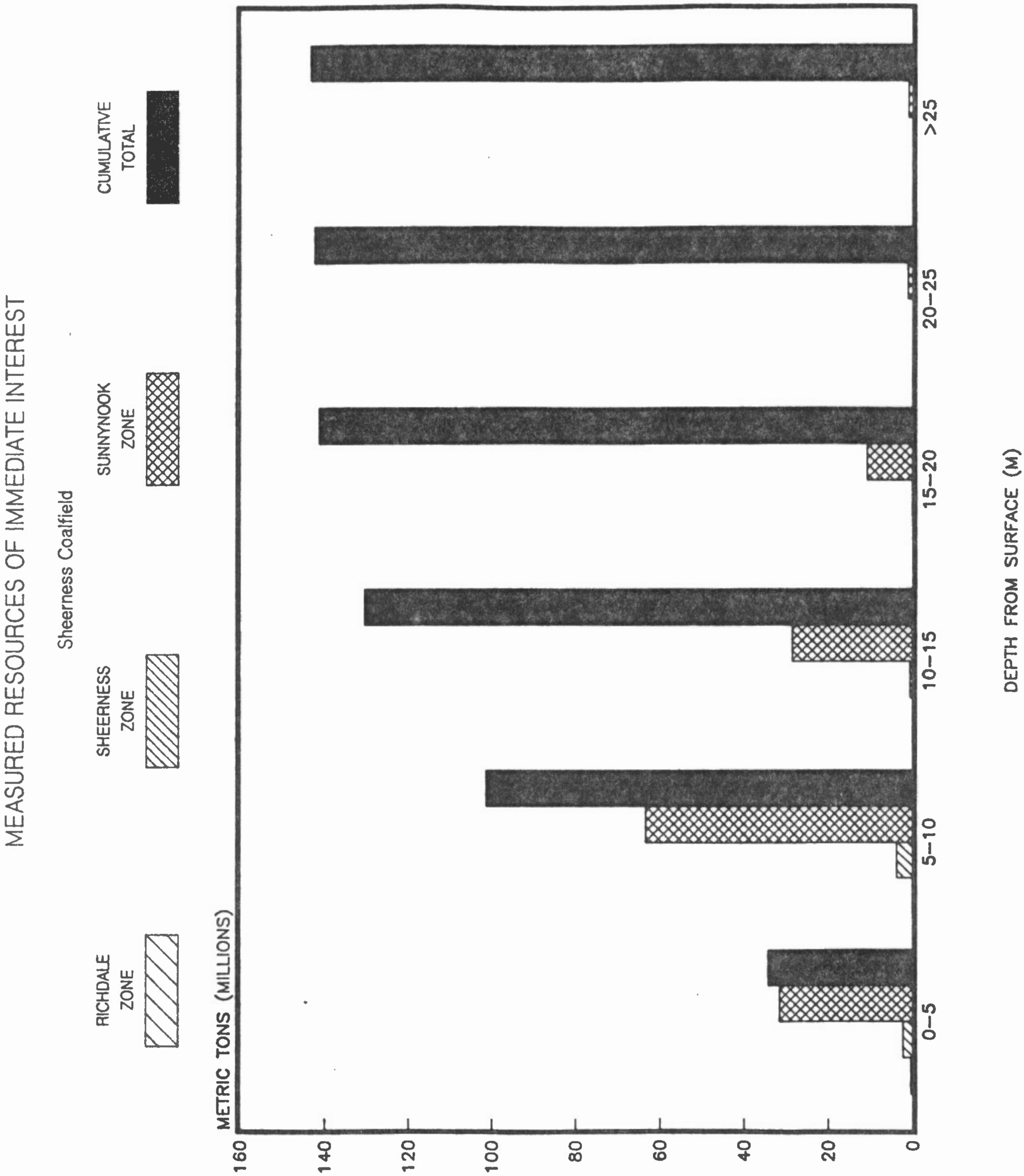

MEASURED RESOURCES OF IMMEDIATE INTEREST
Sheerness Coalfield
RICHDALE ZONE
SHEERNESS ZONE
SUNNYNOOK ZONE
CUMULATIVE TOTAL
METRIC TONS (MILLIONS)
160
140
120
100
80
60
40
20
0
0–5
5–10
10–15
15–20
20–25
>25
DEPTH FROM SURFACE (M)

Figure 58.

TABLE 13

Sunnynook Coal Zone

Resources of immediate interest by incremental overburden depths

Depth From Surface (m)	Measured	Indicated	Inferred
	(million metric tons)		
0 - 5	31.455	0.940	0.155
5 - 10	63.260	4.390	0.340
10 - 15	28.470	1.655	1.195
15 - 20	10.735	1.205	0.475
20 - 25	1.125	0.705	0.430
25 - 30	0.340	0.335	0.030
30 - 35	0.210	0.100	-
35 - 40	0.295	0.135	-
40 - 45	0.110	0.040	-
45 - 50	0.015	0.015	-
Totals	136.015	9.520	2.625

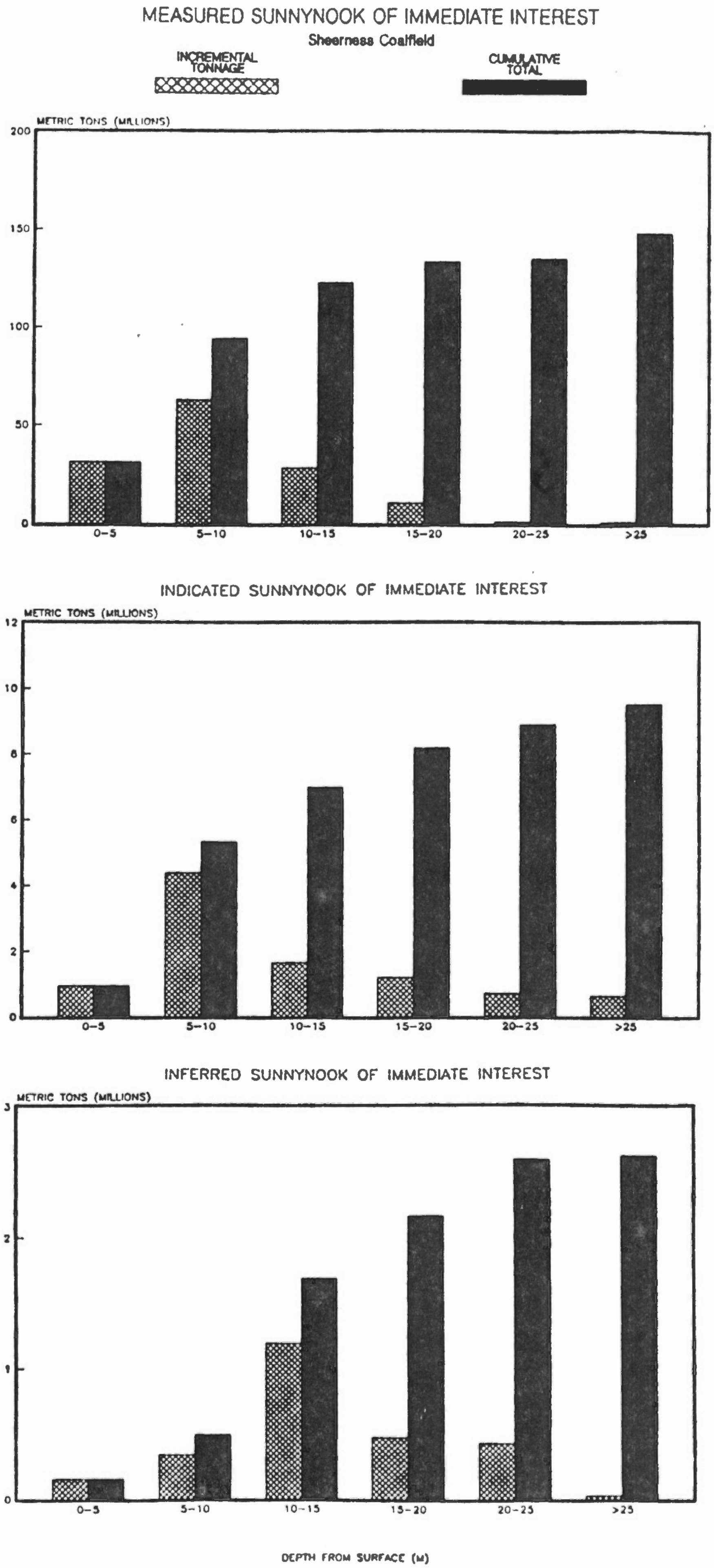

MEASURED SUNNYNOOK OF IMMEDIATE INTEREST
Sheerness Coalfield
INCREMENTAL TONNAGE
CUMULATIVE TOTAL
METRIC TONS (MILLIONS)
200
150
100
50
0
0–5
5–10
10–15
15–20
20–25
>25
INDICATED SUNNYNOOK OF IMMEDIATE INTEREST
METRIC TONS (MILLIONS)
12
10
8
6
4
2
0
0–5
5–10
10–15
15–20
20–25
>25
INFERRED SUNNYNOOK OF IMMEDIATE INTEREST
METRIC TONS (MILLIONS)
3
2
1
0
0–5
5–10
10–15
15–20
20–25
>25
DEPTH FROM SURFACE (M)

Figure 59.

TABLE 14

Sunnynook Coal Zone

Resources of immediate interest by incremental overburden to coal ratios

Overburden to Coal Ratio (BCM/t)	Measured	Indicated	Inferred
	(million metric tons)		
0 - 1	8.415	0.290	-
1 - 2	33.480	2.170	-
2 - 3	34.725	2.735	-
3 - 4	17.930	0.665	0.360
4 - 5	14.660	0.220	0.190
5 - 6	10.145	0.740	0.580
6 - 7	6.255	0.435	0.470
7 - 8	3.465	0.230	0.180
8 - 9	1.805	0.155	0.075
9 - 10	1.070	0.155	0.030
10 - 15	2.910	1.075	0.700
15 - 20	0.530	0.430	0.040
20 - 30	0.555	0.195	-
>30	0.070	0.025	-
Totals	136.015	9.520	2.625

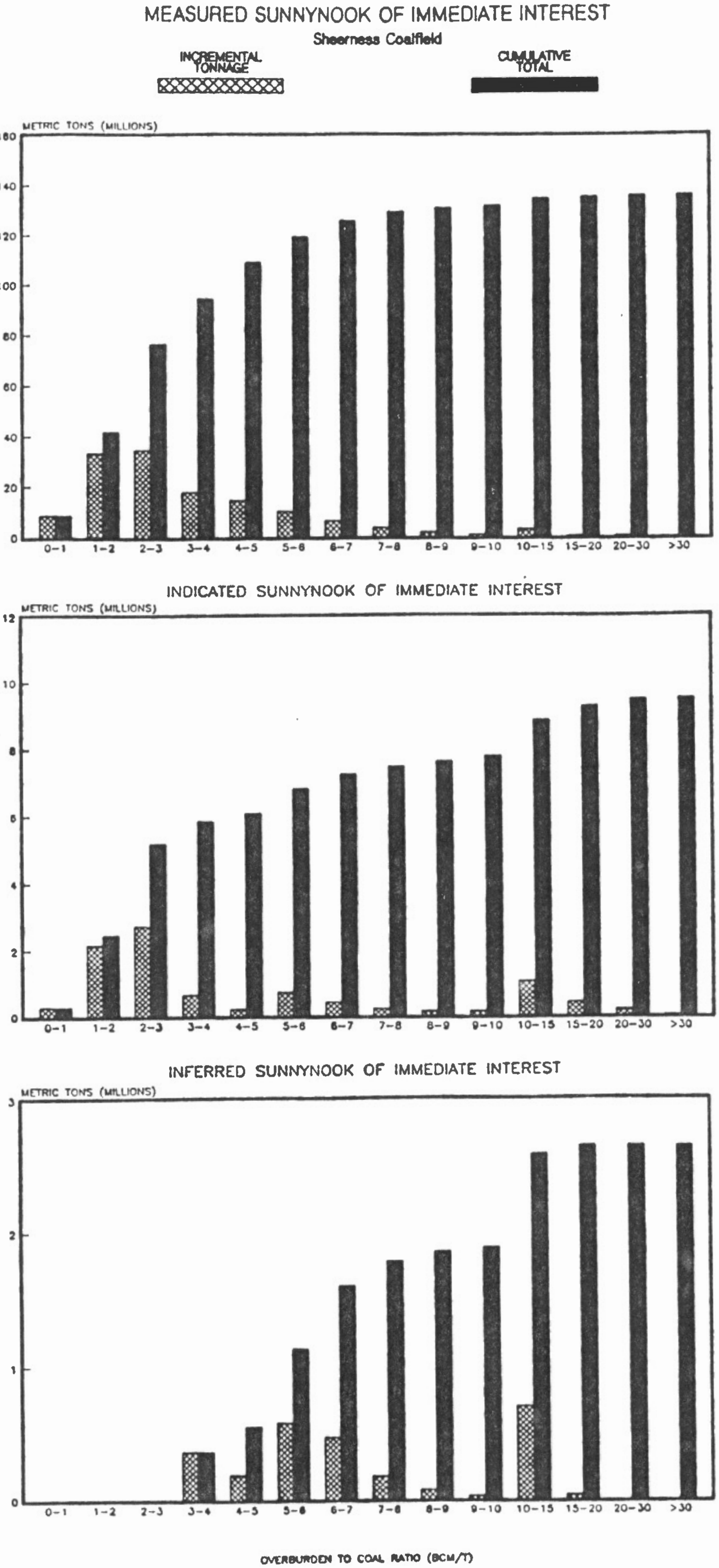

MEASURED SUNNYNOOK OF IMMEDIATE INTEREST
Sheerness Coalfield
INCREMENTAL TONNAGE
CUMULATIVE TOTAL
METRIC TONS (MILLIONS)
0-1 1-2 2-3 3-4 4-5 5-6 6-7 7-8 8-9 9-10 10-15 15-20 20-30 >30
INDICATED SUNNYNOOK OF IMMEDIATE INTEREST
METRIC TONS (MILLIONS)
INFERRED SUNNYNOOK OF IMMEDIATE INTEREST
METRIC TONS (MILLIONS)
OVERBURDEN TO COAL RATIO (BCM/T)

Figure 60.

TABLE 15

Sheerness Coal Zone

Resources of immediate interest by incremental overburden depths

Depth From Surface (m)	Measured	Indicated	Inferred
	(million metric tons)		
0 - 5	2.275	0.265	0.015
5 - 10	3.810	0.370	0.015
10 - 15	0.640	-	-
15 - 20	0.060	-	-
>20	-	-	-
Totals	6.785	0.635	0.030

TABLE 16

Richdale Coal Zone

Resources of immediate interest by incremental overburden depths

Depth From Surface (m)	Measured	Indicated	Inferred
	(million metric tons)		
0 - 5	0.465	-	-
5 - 10	0.060	-	-
10 - 15	0.015	-	-
>15	-	-	-
Totals	0.540	-	-

TABLE 17

Sunnynook Coal Zone

Resources of future interest by incremental overburden to coal ratios

Overburden to Coal Ratio (BCM/t)	Measured	Indicated	Inferred
	(million metric tons)		
0 - 1	0.150	0.110	0.020
1 - 2	0.360	0.125	0.010
2 - 3	0.490	0.075	-
3 - 4	0.810	0.010	0.010
4 - 5	0.870	0.180	0.160
5 - 6	1.035	0.160	0.190
6 - 7	0.860	0.105	0.155
7 - 8	0.710	0.260	0.215
8 - 9	1.075	0.170	0.370
9 - 10	0.815	0.100	0.305
10 - 15	2.830	0.570	0.955
15 - 20	1.445	0.660	0.490
20 - 30	1.685	0.490	0.370
30 - 40	0.565	0.430	0.045
> 40	0.365	0.275	0.560
Totals	14.065	3.270	3.855

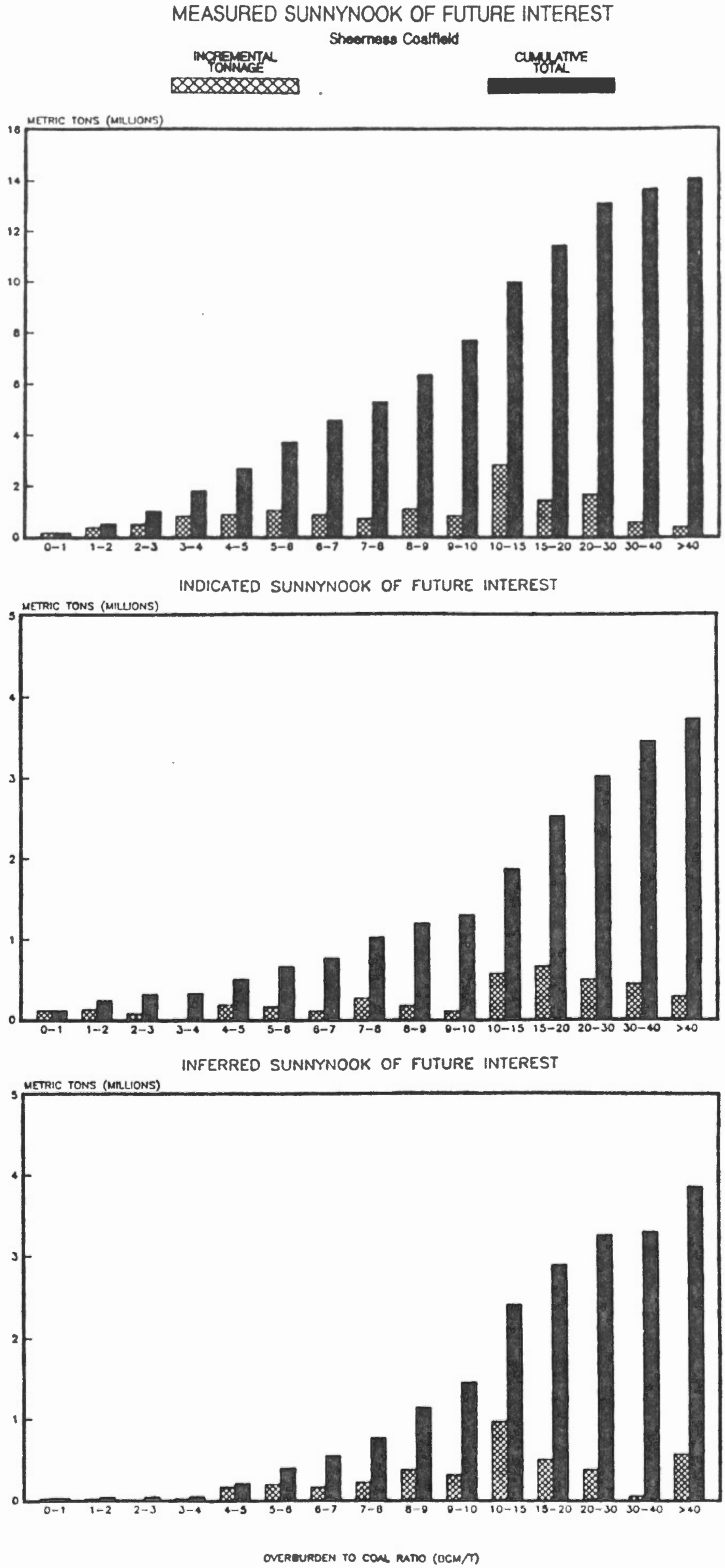

MEASURED SUNNYNOOK OF FUTURE INTEREST
Sheerness Coalfield
INCREMENTAL TONNAGE
CUMULATIVE TOTAL
METRIC TONS (MILLIONS)
0-1
1-2
2-3
3-4
4-5
5-6
6-7
7-8
8-9
9-10
10-15
15-20
20-30
30-40
>40
INDICATED SUNNYNOOK OF FUTURE INTEREST
METRIC TONS (MILLIONS)
INFERRED SUNNYNOOK OF FUTURE INTEREST
METRIC TONS (MILLIONS)
OVERBURDEN TO COAL RATIO (BCM/T)

Figure 61.

Coal Quality

Available coal quality data were entered into the database using a program named "QUALITY". In addition to storing entered data into the ply-analysis file of the database, QUALITY provides facilities for modifying, displaying and retrieving the data. The types of analyses which can be entered into the database are shown in Table 3. The proximate and ultimate data can be entered, changed or retrieved on any of the following moisture bases: dry, as analysed, air dried, as received, equilibrium, expected or any user-specified moisture base. The program allows the retrieval of ply analyses for user-specified coal beds according to one or more of the following five different types of output:

proximate data

ultimate data

ash composition data

ash properties data

sample information data

The program also allows the selective retrieval of data from boreholes which lie either inside or outside of a user-specified polygon.

An integrated set of programs named "COMBINE" was used to composite ply analyses of coal occurring between user-specified correlated coal beds. Analytical data determined on a weight per cent basis were combined according to proportional weights of sampled plies. Some quality attributes, such as free swelling index and hardgrove grindability, were combined as the arithmetic mean of ply data. Other attributes, such as ash fusion, were combined as a volume weighted mean.

The relative weights of sampled plies were determined by first estimating an in situ bulk specific gravity for each ply. These specific gravities were used, together with the thickness of each ply, to composite data. The bulk specific gravity of a ply was estimated as a function of ash content of the ply and coal rank, according to the function illustrated in Figure 62.

Analyses of a total of 682 sampled plies from 327 boreholes were entered into the Sheerness Coalfield database. The distributions of these data by coal zone, contributing company and year sampled are summarized in Table 18.

IN SITU BULK S.G. VS % ASH

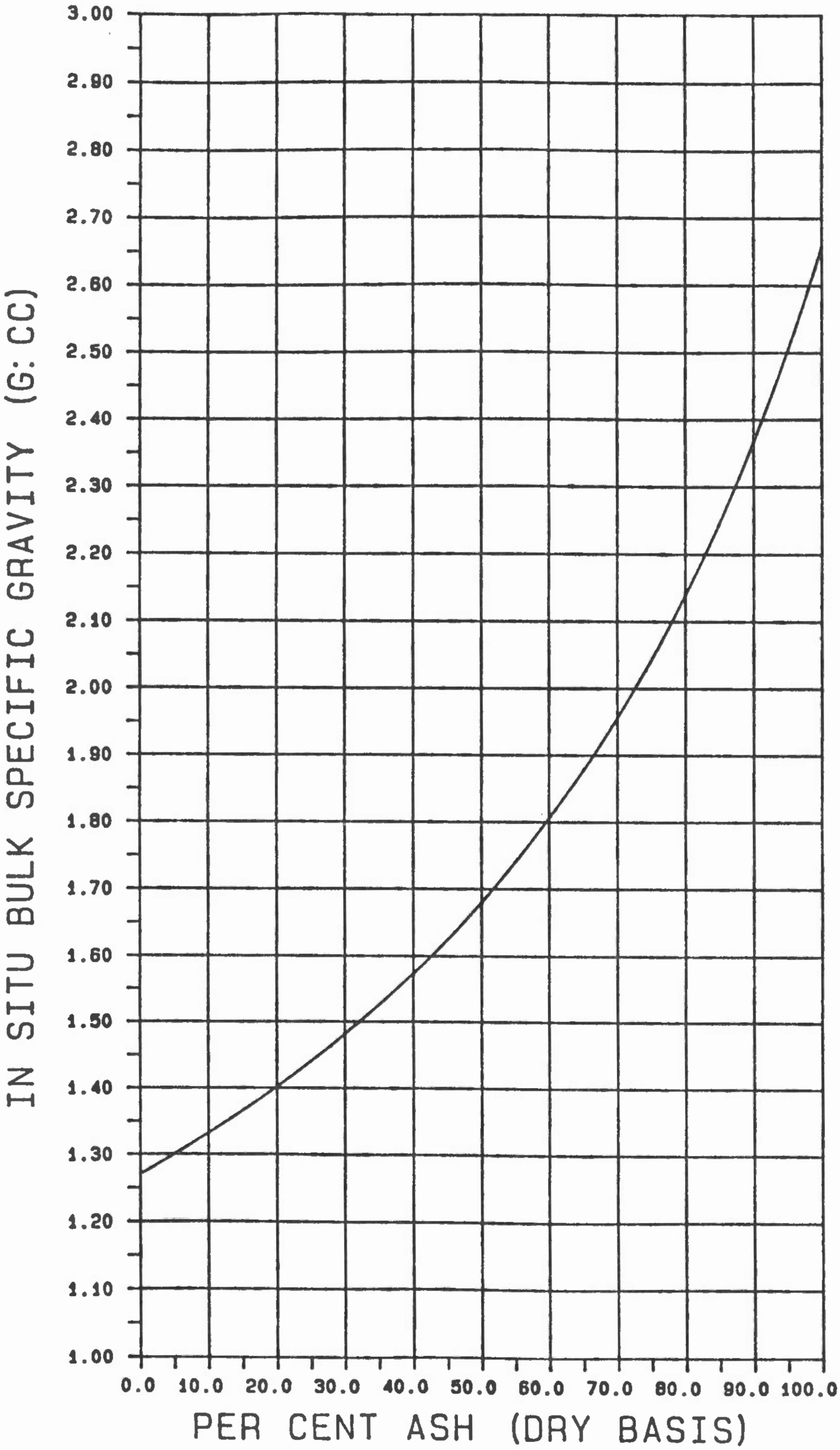


Figure 62.

TABLE 18

Summary of available coal quality data

Coal Zone	Contributing Company	Year Sampled	No. of Zone Intersections	No. of Plies
Sunnynook	Alberta Power	1974	68	83
	Luscar Ltd.	1976	79	108
	Luscar Ltd.	1977	54	115
	Luscar Ltd.	1980	86	142
	Luscar Ltd.	1981	26	37
Sub-totals: Sunnynook			313	485
Sheerness	Alberta Power	1974	23	23
	Luscar Ltd.	1976	38	40
	Luscar Ltd.	1977	31	36
	Luscar Ltd.	1980	48	52
	Luscar Ltd.	1981	7	10
Sub-totals: Sheerness			147	161
Roselynn	Alberta Power	1974	1	1
	Luscar Ltd.	1976	12	12
	Luscar Ltd.	1977	1	1
	Luscar Ltd.	1980	11	11
	Luscar Ltd.	1981	1	1
Sub-totals: Roselynn			26	26
Richdale	Luscar Ltd.	1976	4	4
	Luscar Ltd.	1980	6	6
Sub-totals: Richdale			10	10
Totals - all zones			496	682

All samples were analysed for ash content and/or unit heat value. Some samples were also analysed for the following attributes:

TABLE 19

ANALYSED COAL QUALITY ATTRIBUTES
(excluding ash content and unit heat value)

ATTRIBUTE	ZONE	NO. OF SAMPLES
VOLATILES / FIXED CARBON	Sunnynook	67
	Sheerness	17
	Roselynn	1
SULPHUR	Sunnynook	38
	Sheerness	6
	Roselynn	1
ASH FUSION	Sunnynook	6
	Sheerness	1
ASH COMPOSITION	Sunnynook	3
HARDGROVE	Sunnynook	5

Coal quality sample populations were adequate for defining distributions of ash content and unit heat value for Sunnynook and Sheerness zones only. These zones contain virtually all of the resources of immediate interest. A posting map of per cent dry ash content, dry unit heat values and aggregate sampled thicknesses for the Sunnynook Coal Zone are provided in Figure 63. Per cent dry ash and dry, mineral-matter-free unit heat values were gridded according to previously described procedures. Isoquality maps of the distributions of the gridded values are provided in Figures 64 and 65 respectively. Distributions of ash and unit heat values for Sunnynook coal at a 25 per cent moisture base are shown in Figures 66 and 67 respectively. These distributions should approximate "as-mined" expectations for the zone. Similar posting and contour maps for the Sheerness zone are provided in Figures 68 to 72. The average per cent ash contents and unit heat values for these coal zones are as follows:

TABLE 20

Mean ash contents and unit heat values of Sunnynook and Sheerness coal zones

Zone	Mean Ash (%)		Mean Unit Heat (mj/kg)	
	Dry	"as-mined"	Dmmf	"as-mined"
Sunnynook	17.4	13.0	28.85	17.74
Sheerness	24.4	18.3	29.05	16.11

Data pertaining to other coal quality attributes were arithmetically averaged over all samples for the Sheerness resource (Table 21). Insufficient data are available to consider these averages reliable for any purpose except an approximate indication of each attribute's value.

TABLE 21

Hypothetical coal quality model for Sheerness Coalfield

Proximate Analysis (Dry Basis)

Ash	18.5 %
Volatile Matter	44.5 %
Fixed Carbon	37.0 %
Sulphur	0.6 %
Heat Value	23.5 mj/kg

Ash Fusion Temperatures (degrees C - reducing environment)

Initial Deformation	1265
Spherical	1300
Hemispherical	1330
Fluid	1380

Hardgrove Grindability 34

Ash Analysis

SiO_2	55.8 %
Al_2O_3	18.8 %
Fe_2O_3	4.1 %
CaO	7.7 %
MgO	0.1 %
Na_2O	1.8 %
K_2O	1.3 %
SO_3	7.3 %
P_2O_5	0.1 %
TiO_2	0.6 %
Undetermined	2.4 %

CONCLUDING REMARKS

A knowledge of the mechanisms for syndepositional seam splitting and controls to postdepositional seam deformations can lead to the development of efficient, rationalized exploration programs. During an exploration program, the early identification of possible depositional environments from distinguishable lithologic relationships in the borehole data can provide clues as to where the most attractive resource potential might be situated. This study provides information regarding possible depositional settings and depositional processes, along with associated characteristic lithologic relationships, which can be valuable when assessing resource potential of laterally equivalent coal-bearing strata.

In addition to providing a framework for estimating the distribution, quantity and quality of the coal resource, the geologic model established for the Sheerness Coalfield is an effective predictive tool to assist the planning of efficient exploitation of the resource. Furthermore, an understanding of the Sheerness Coalfield provides a basis from which other laterally equivalent coal-bearing strata of the lower Horseshoe Canyon Formation might be initially considered where less substantive data are available.

The geologic model can be useful for geotechnical, hydrological and environmental studies of a mining area. Definition of coal distribution is an essential prerequisite of mine designing. An understanding of the types and distributions of noncoal lithologic units in a mining area can be useful for estimating production rates of mining equipment, or for anticipating possible changes in productivities. Variability in the shapes of seam partings can affect the planning of coaling operations for achieving desired run-of-mine quality results.

From this and other similar studies, exploration guidelines can be developed to assist those engaged in exploring the coal resources of the lower Horseshoe Canyon Formation to optimize their activities.

In addition to providing contributing companies their respective data in computer-processable form, along with a report summarizing the analysis of that data, this report and computer tapes of all data have been included in the files of the National Coal Inventory. The resource evaluation can be readily upgraded should additional information become available or resource evaluating parameters change.

TABLE 22

COALFIELD MODEL APPLICATIONS

MINE DESIGNING

ANCILLARY DEVELOPMENT PLANNING

PRODUCTION SCHEDULING

- estimating coal release quantities
- estimating digging productivities
- forecasting run-of-mine coal qualities

GEOTECHNICAL STUDIES

HYDROLOGICAL STUDIES

EXPLORATION PLANNING

The resources which were dedicated to the Sheerness Coalfield evaluation, from the time of acquisition of raw and uninterpreted borehole data, to the formulation of the initial draft report of the resource analysis, included the following:

* Organization and interpretation of borehole data, entry of lithologic and borehole identification data into database and production of minilogs	9 man-months
* Establishment of correlation framework, geologic and depositional models and resource estimates.	12 man-months
* Incidental data entry, project management, ancillary functions, etc.	3 man-months
* Computer utilization	6,000,000 cpu-seconds

An average of approximately 100 metres per man-day of hard copy borehole data were interpreted, entered into the computer-accessible database and displayed in the form of both fullscale and miniature lithology logs.

Approximately one-third of the computer time utilized was on an HP3000 - Series 2 computer with the balance on an HP3000 - Series 68 computer.

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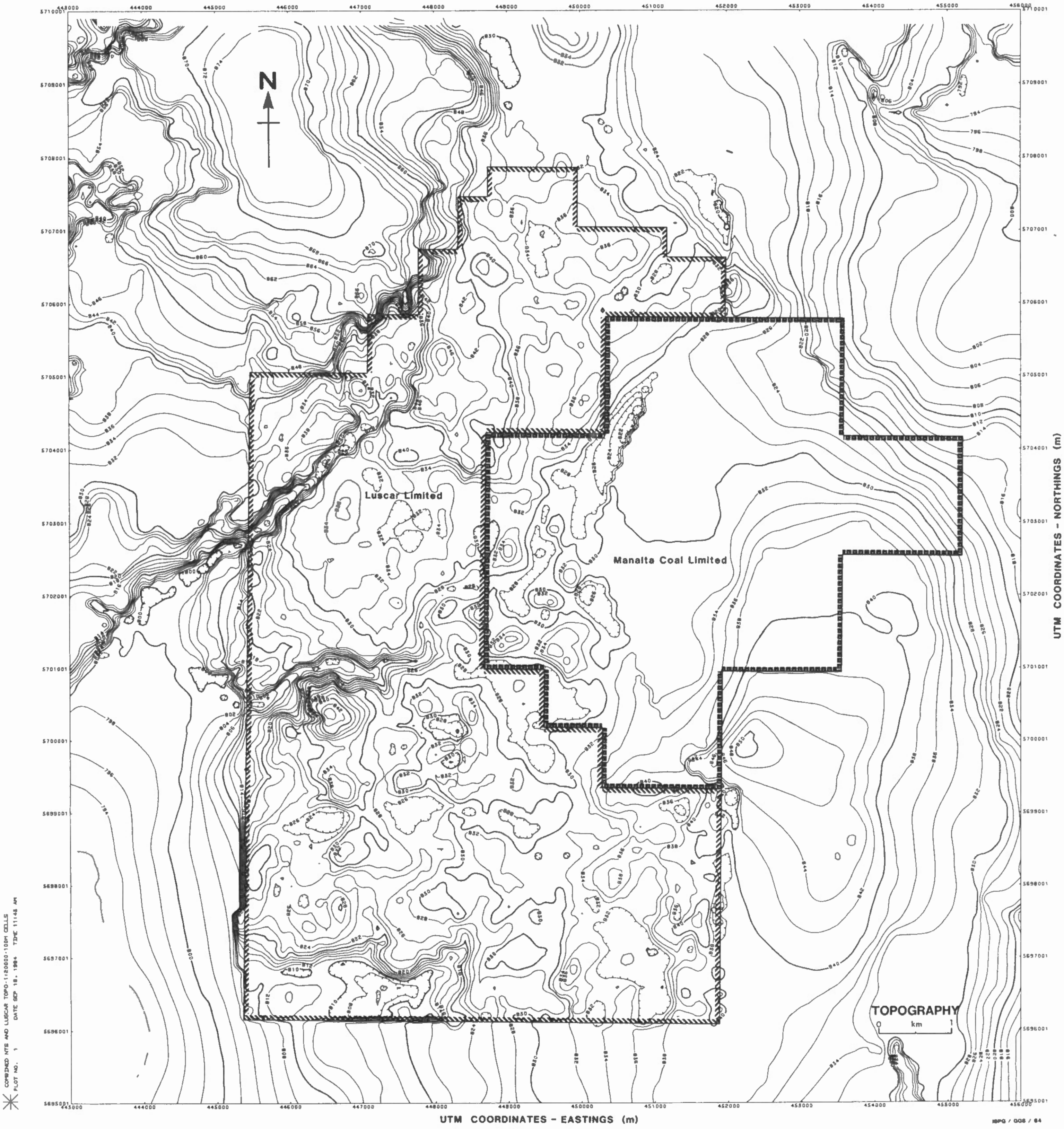
GEOLOGY AND COAL RESOURCES OF THE SHEERNESS COALFIELD, SOUTH-CENTRAL ALBERTA

*** MAP FOLIO ***

FIGURE 2


N
Luscar Limited
Manalta Coal Limited
TOPOGRAPHY
km
UTM COORDINATES - EASTINGS (m)
UTM COORDINATES - NORTHINGS (m)
COMBINED NTS AND LUSCAR TOPO-1:20000-100M CELLS
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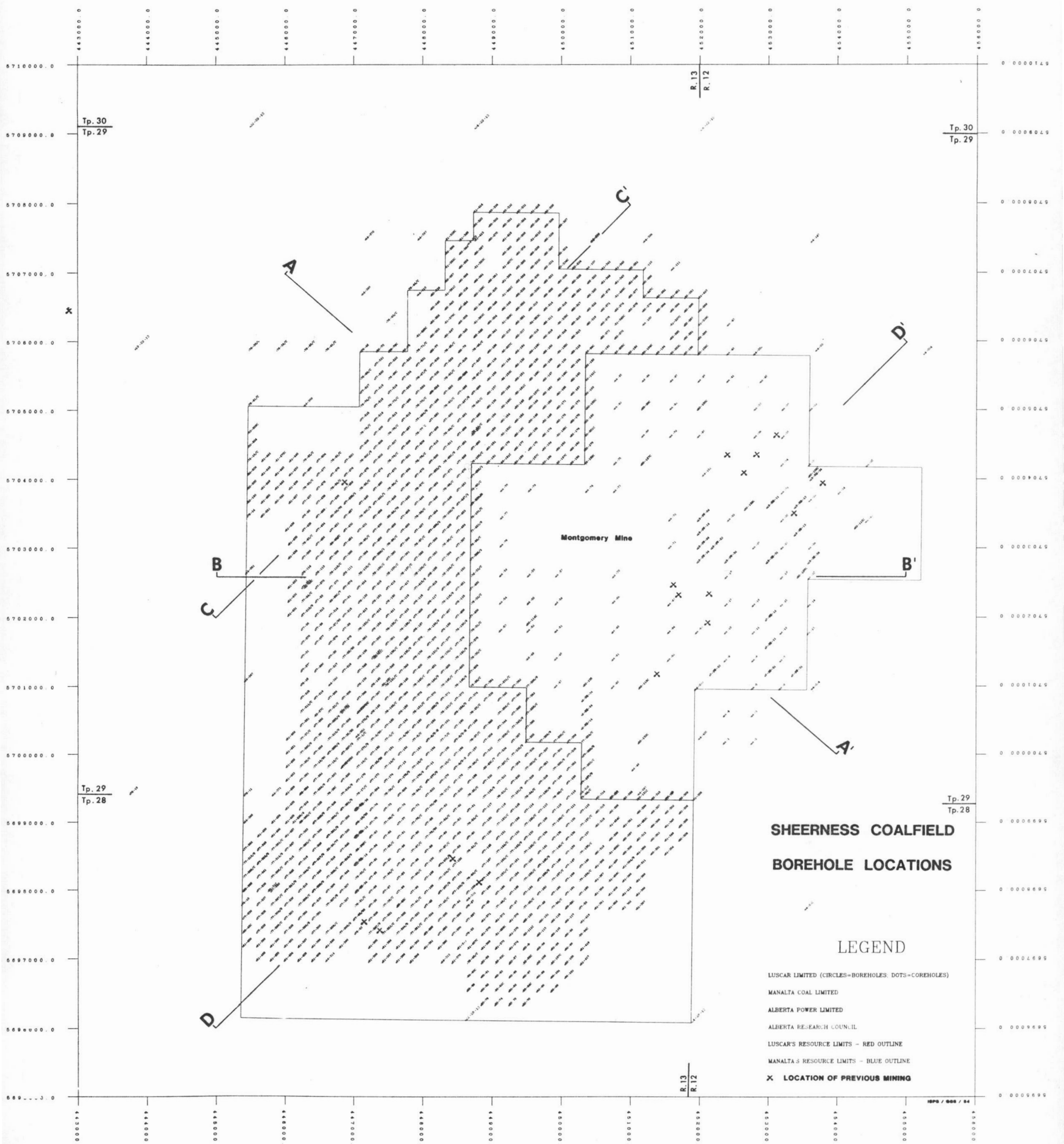
IBPG / GGS / 84

FIGURE 3



SHEERNESS COALFIELD
BOREHOLE LOCATIONS
LEGEND
LUSCAR LIMITED (CIRCLES=BOREHOLES; DOTS=COREHOLES)
MANALTA COAL LIMITED
ALBERTA POWER LIMITED
ALBERTA RESEARCH COUNCIL
LUSCAR'S RESOURCE LIMITS - RED OUTLINE
MANALTA'S RESOURCE LIMITS - BLUE OUTLINE
X LOCATION OF PREVIOUS MINING
Montgomery Mine
Tp. 30
Tp. 29
Tp. 28
R. 13
R. 12
A
A'
B
B'
C
C'
D
D'

FIGURE 10

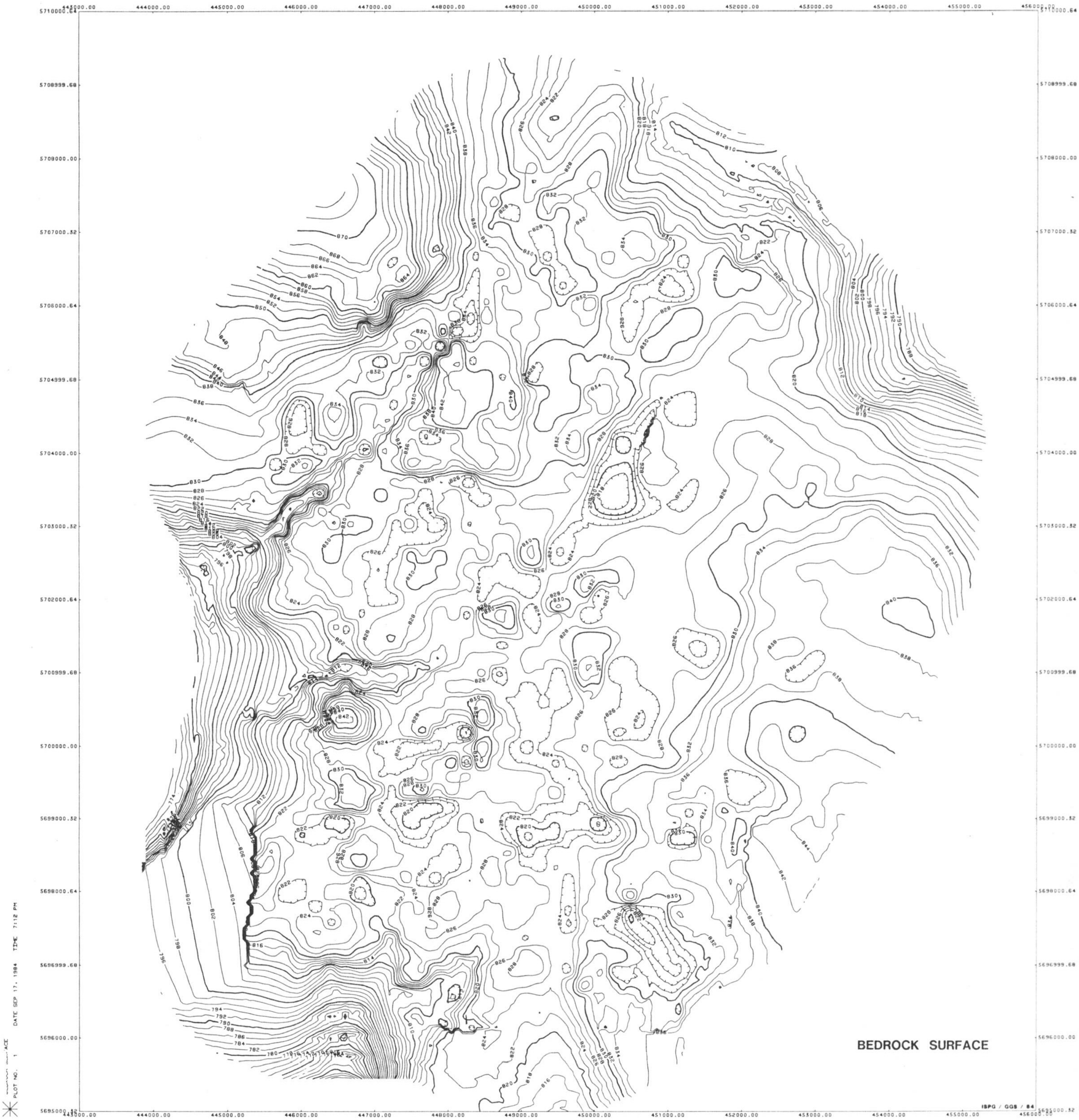

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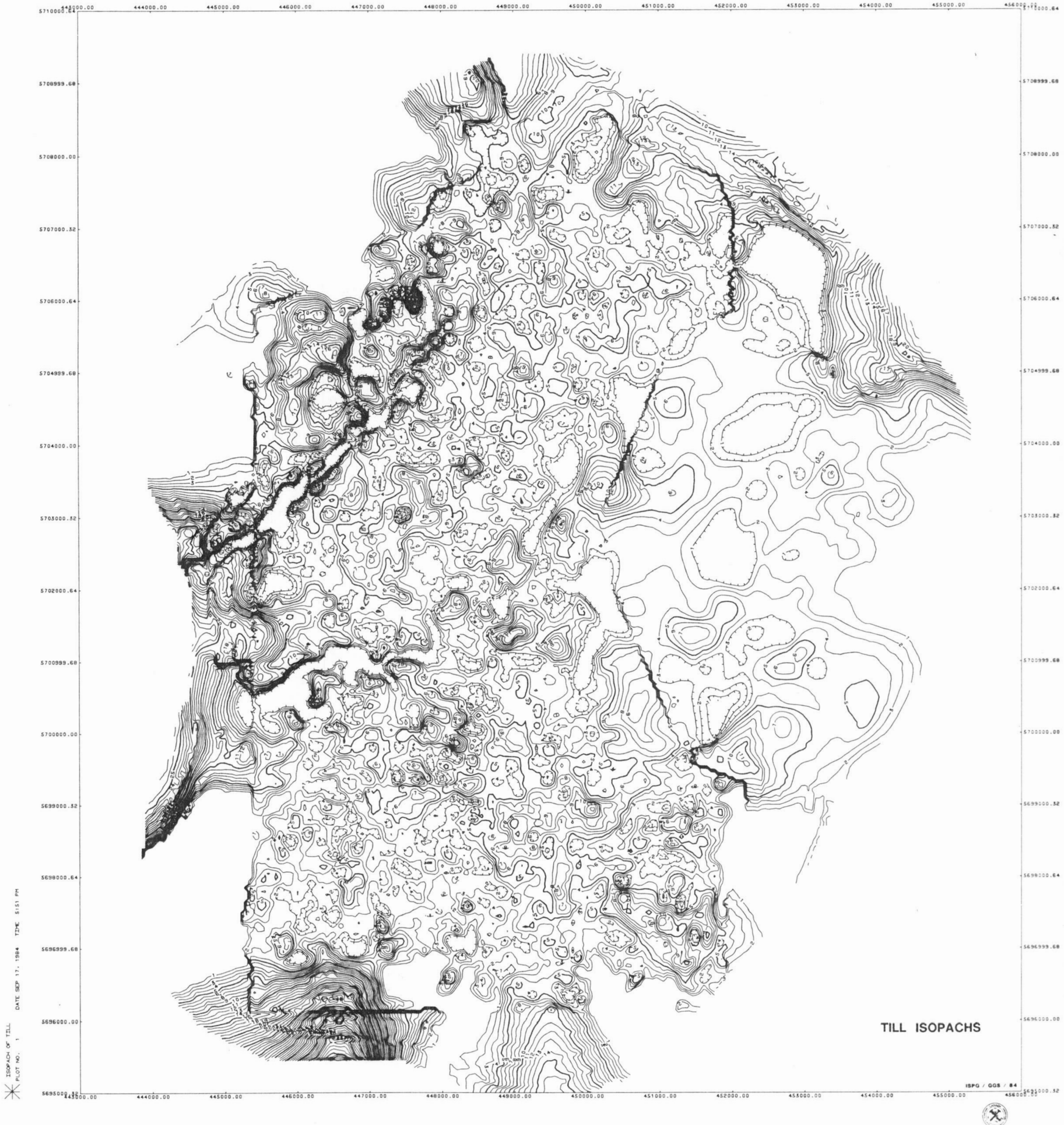
FIGURE 11



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PLOT NO. 1
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445000.00
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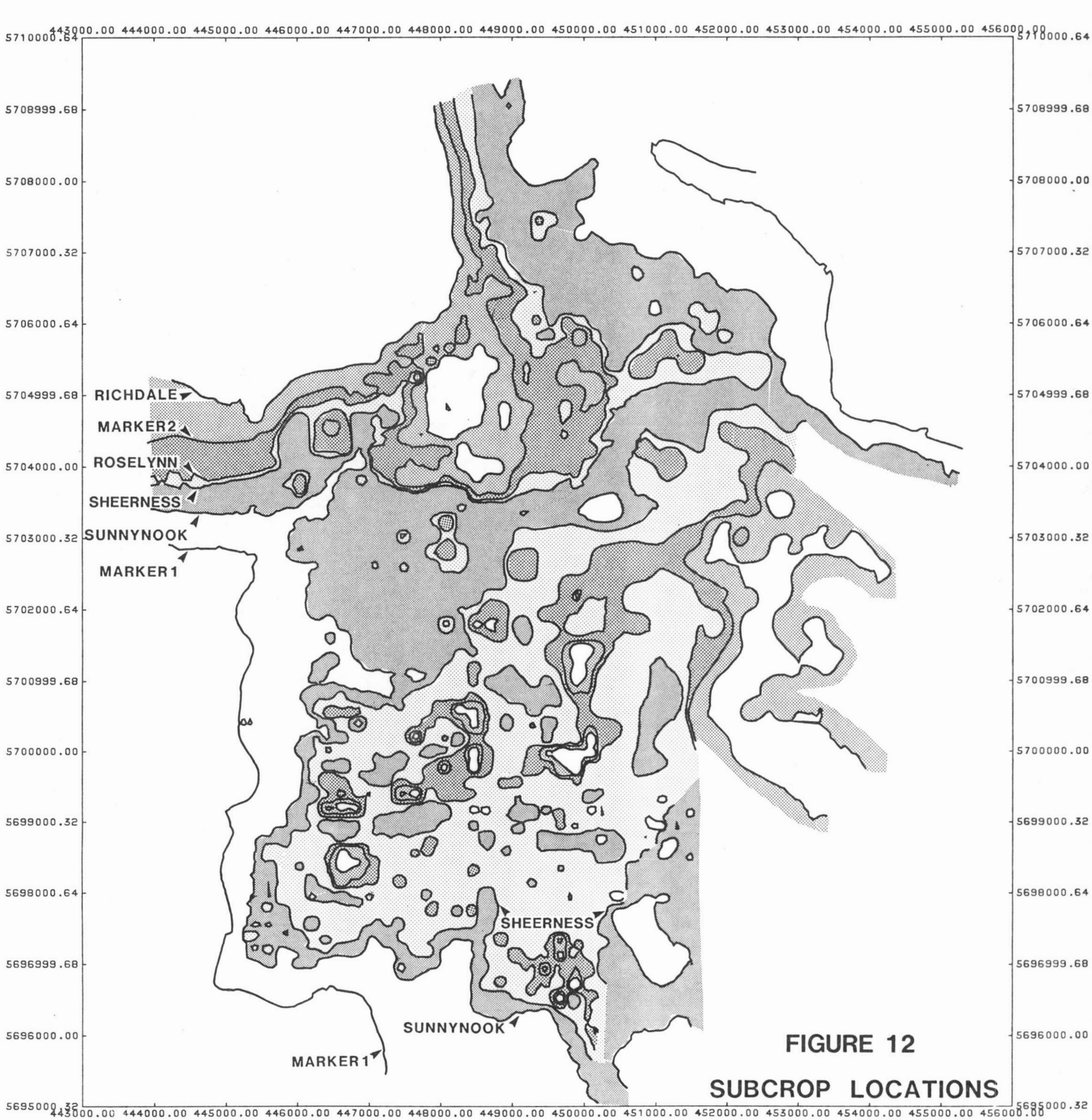
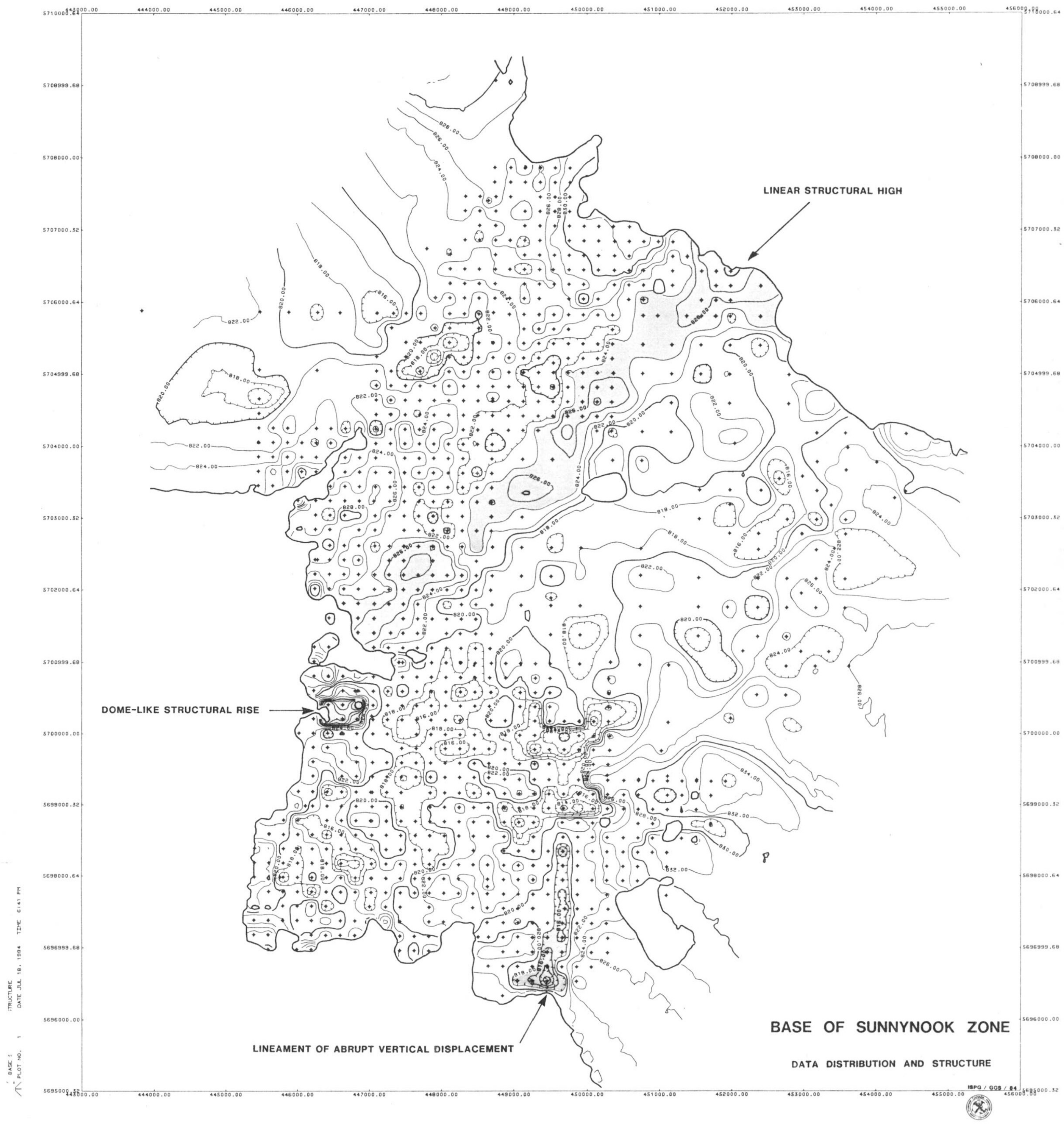


FIGURE 12
SUBCROP LOCATIONS

FIGURE 13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DOME-LIKE STRUCTURAL RISE
LINEAMENT OF ABRUPT VERTICAL DISPLACEMENT
BASE OF SUNNYNOOK ZONE
DATA DISTRIBUTION AND STRUCTURE
ISPG / GGS / 84

FIGURE 14

BASE OF SHEERNESS ZONE

DATA DISTRIBUTION AND STRUCTURE

FIGURE 15

BASE ROSE LYNN - STRUCTURE AND DATA
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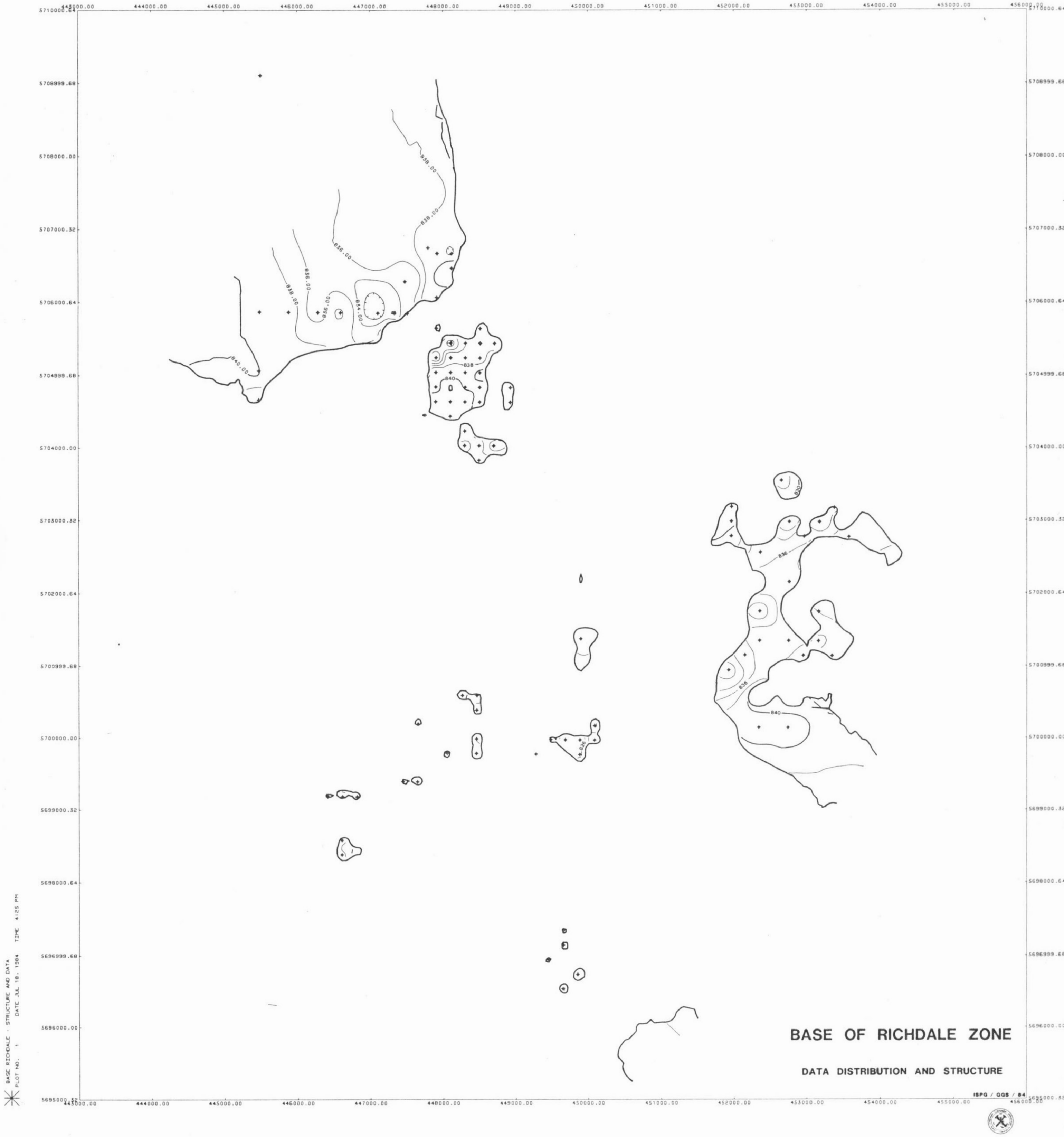
FIGURE 16



BASE OF RICHDALE ZONE
DATA DISTRIBUTION AND STRUCTURE
ISPG / GGS / 84

FIGURE 17a

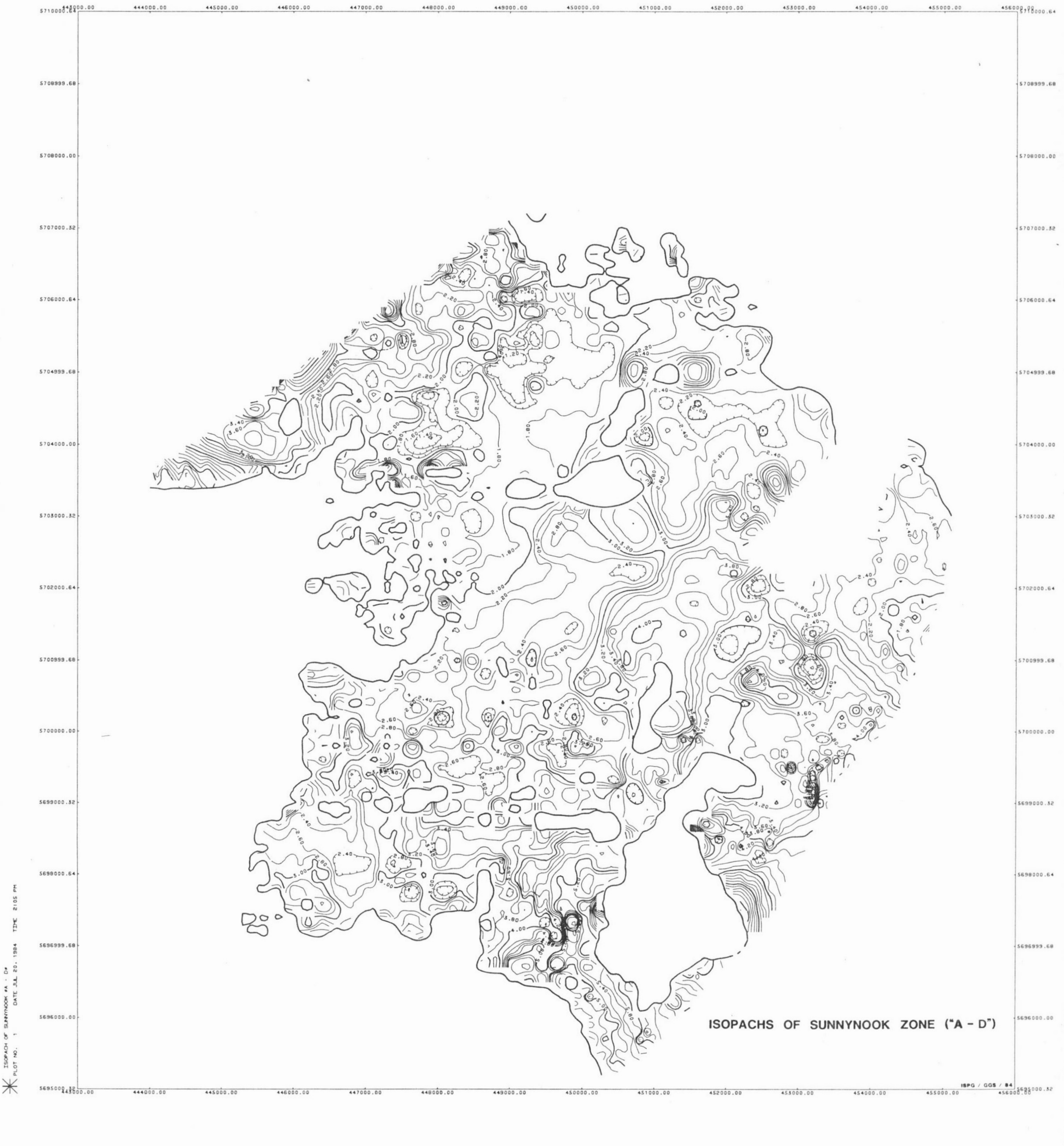
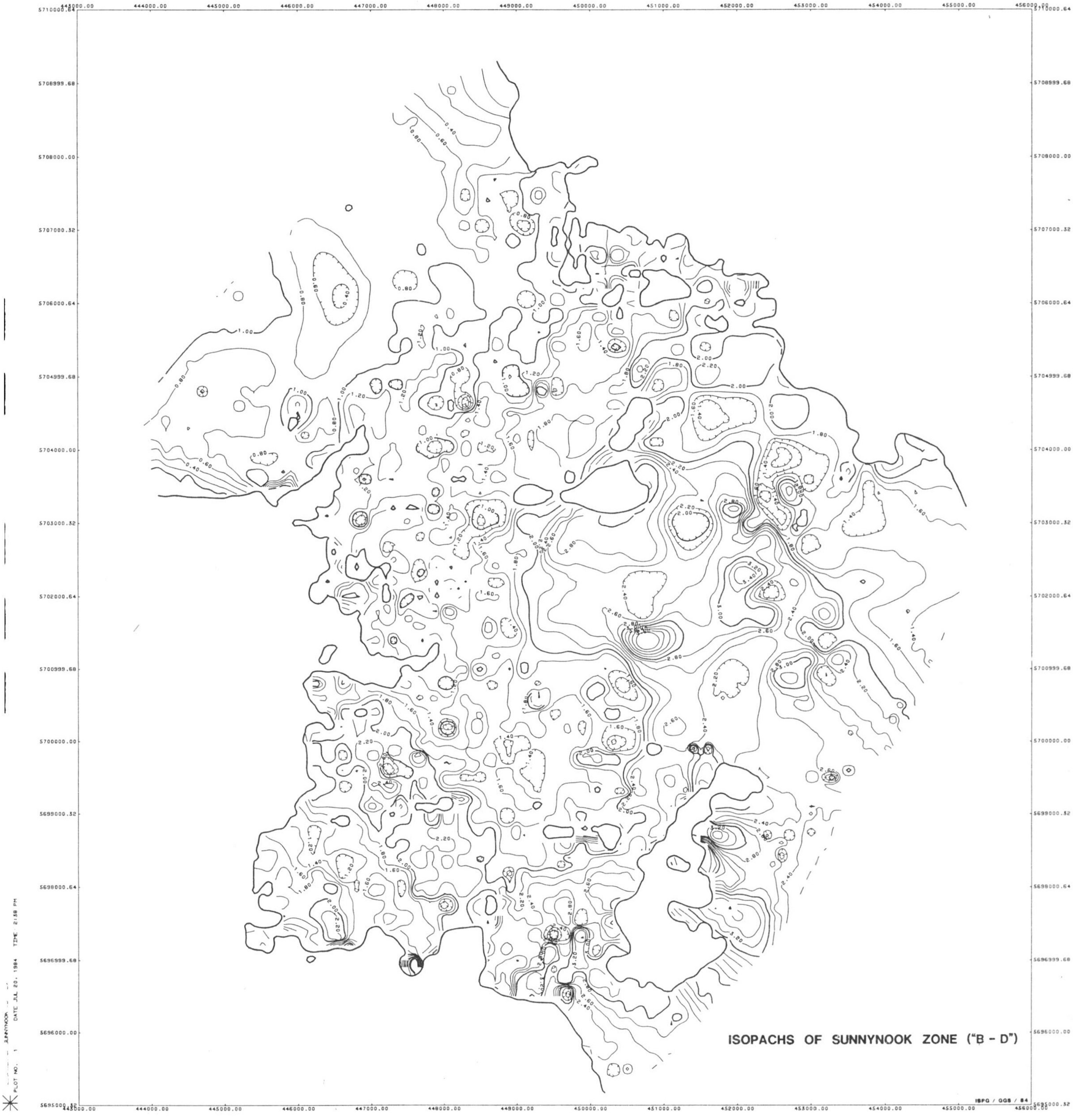
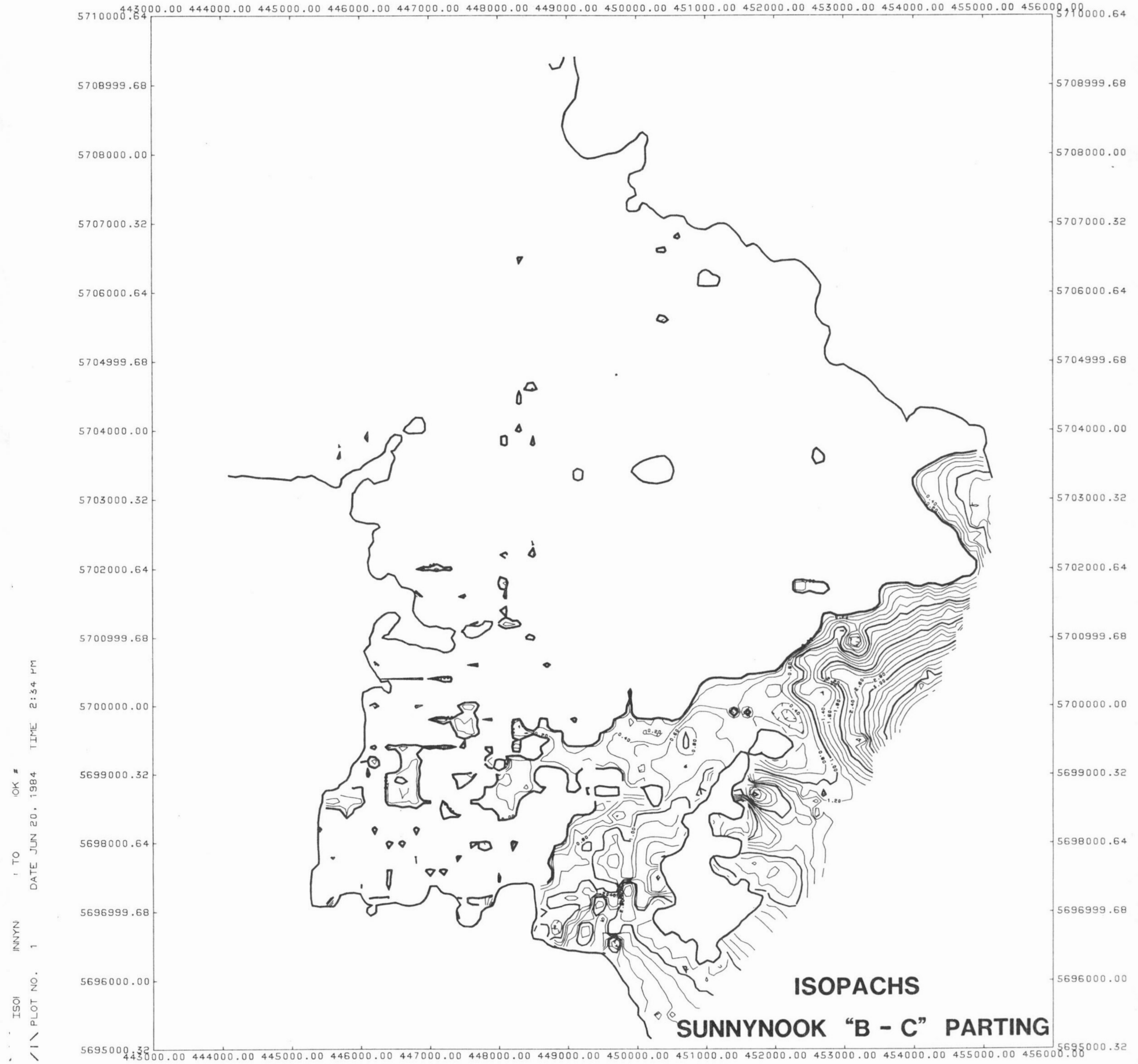

ISOPACHS OF SUNNYNOOK ZONE ("A - D")
ISPG / GGS / 84
ISOPACH OF SUNNYNOOK #A - D#
PLOT NO. 1
DATE JUL 20, 1984
TIME 2105 PM

FIGURE 17b



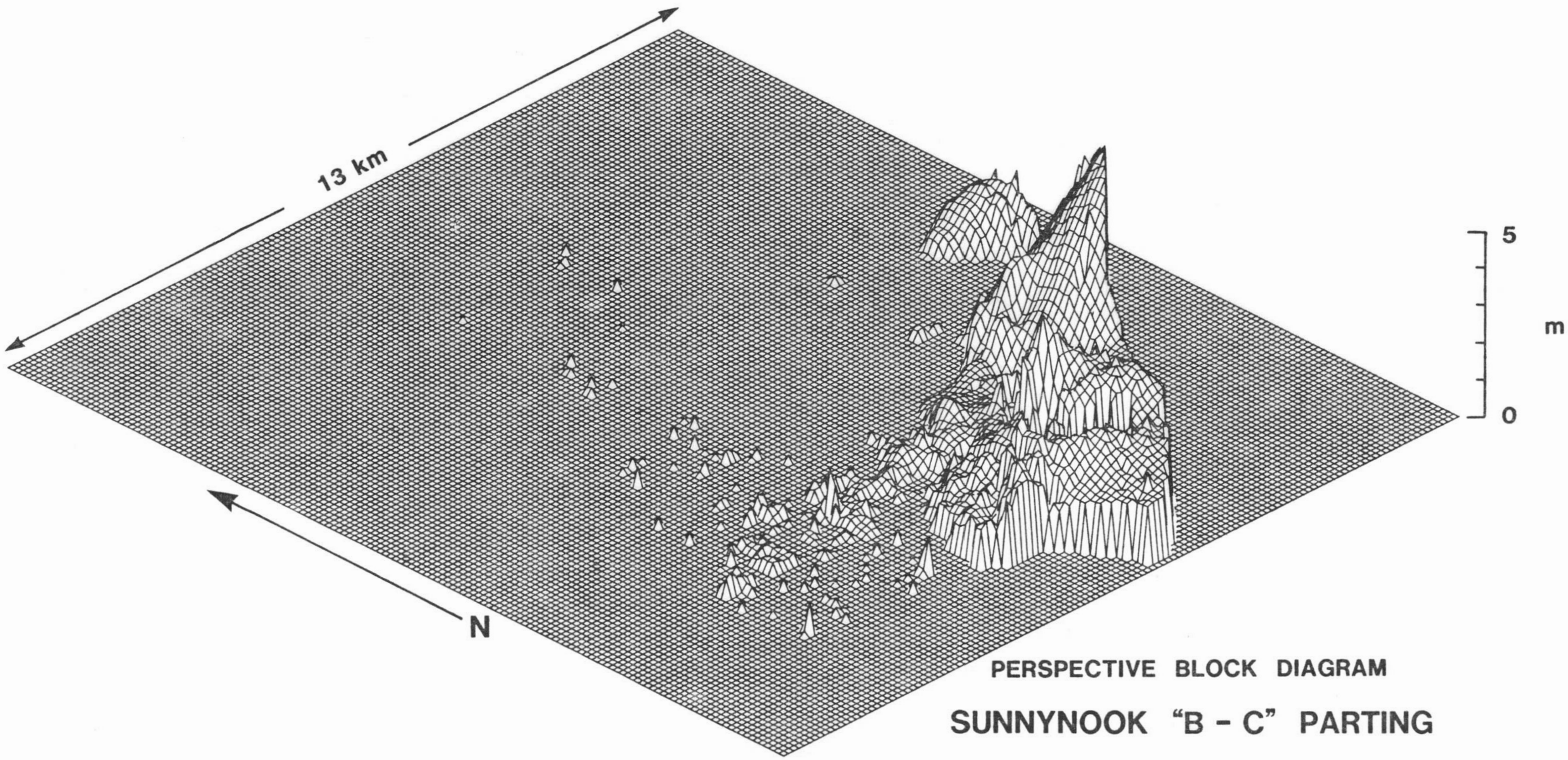
ISOPACHS OF SUNNYNOOK ZONE ("B - D")

FIGURE 18a



ISPG / GGS / 84

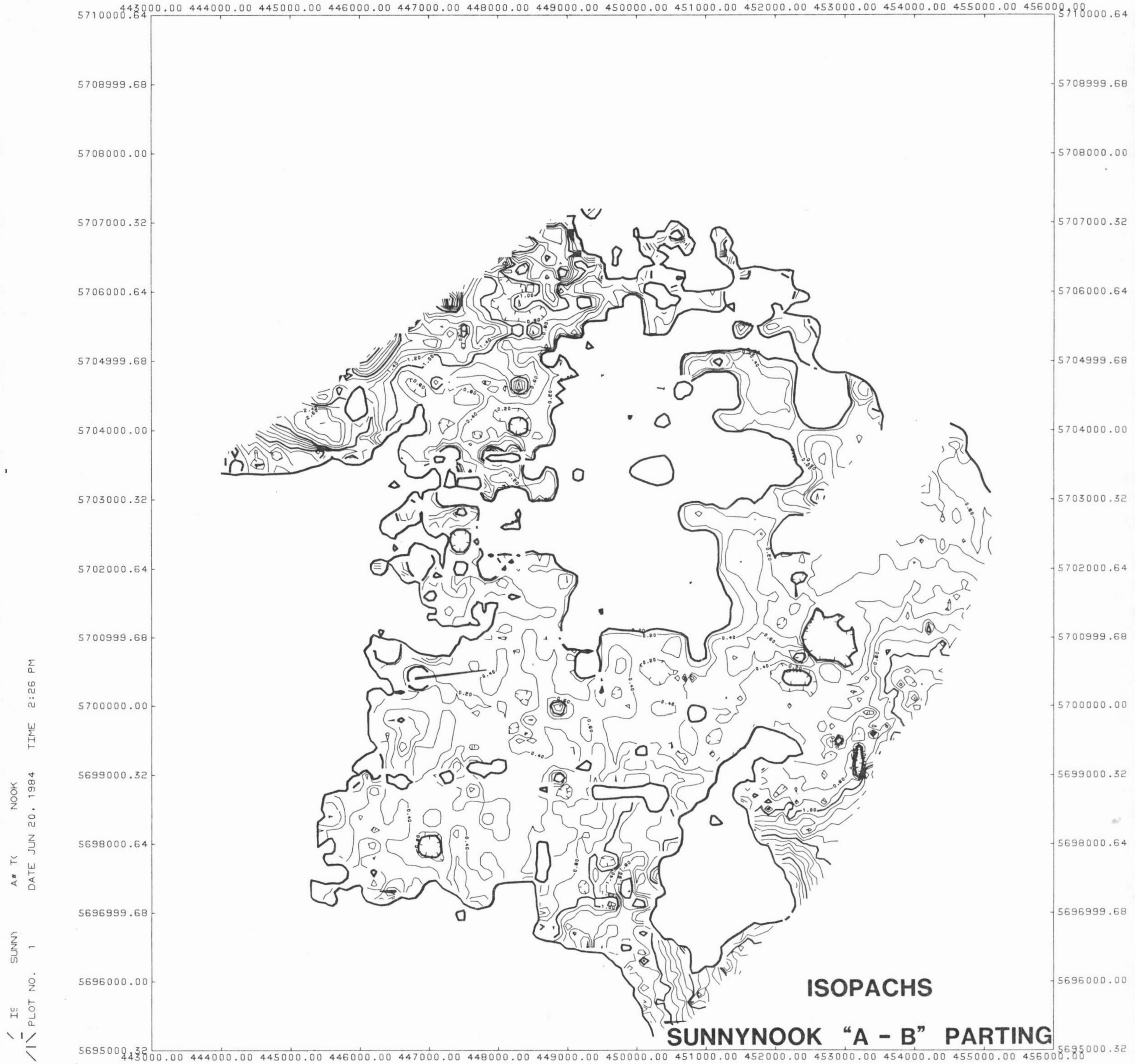
FIGURE 18b



PERSPECTIVE BLOCK DIAGRAM

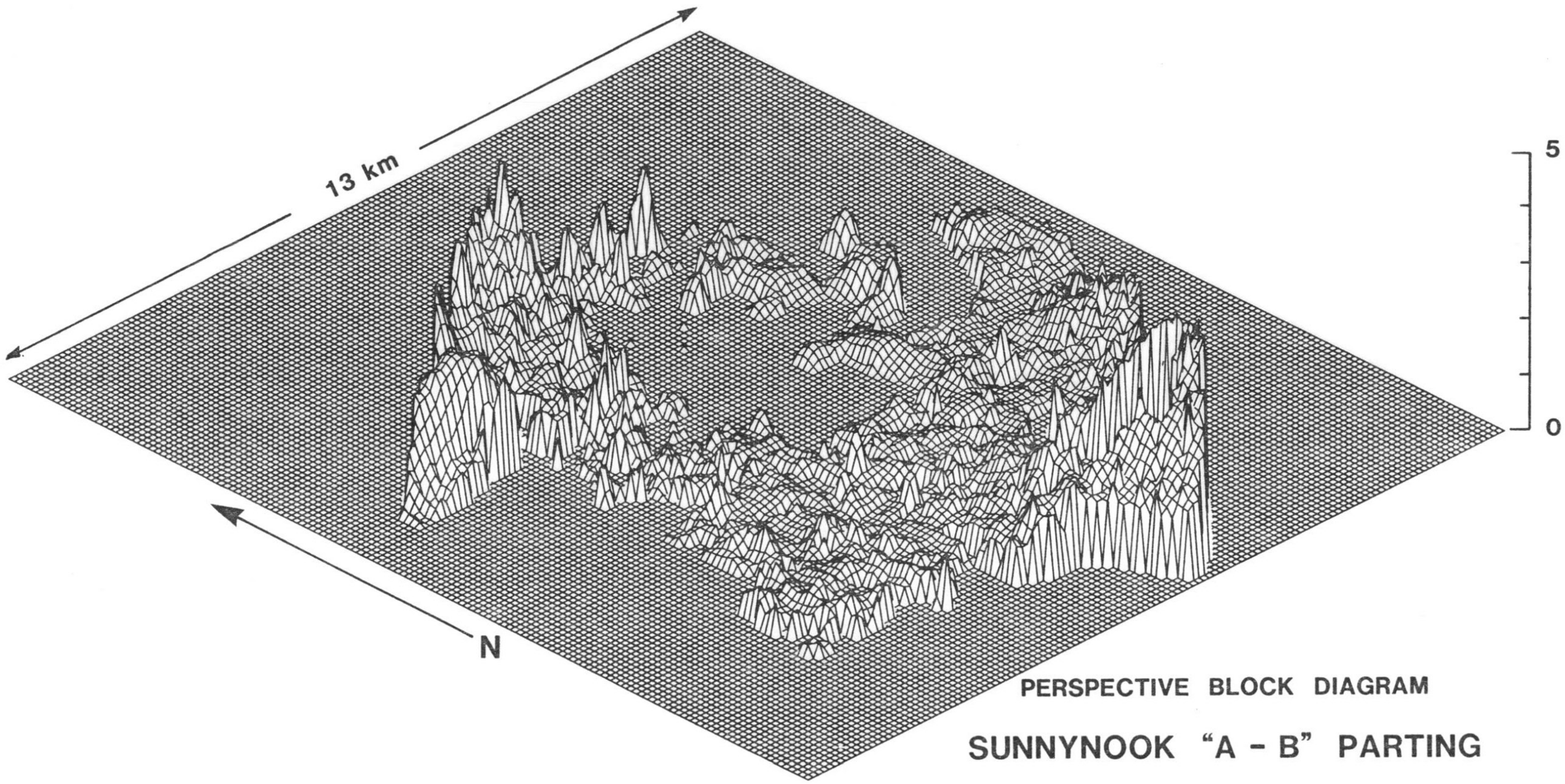
SUNNYNOOK “B - C” PARTING

FIGURE 19a



ISPG / GGS / 84

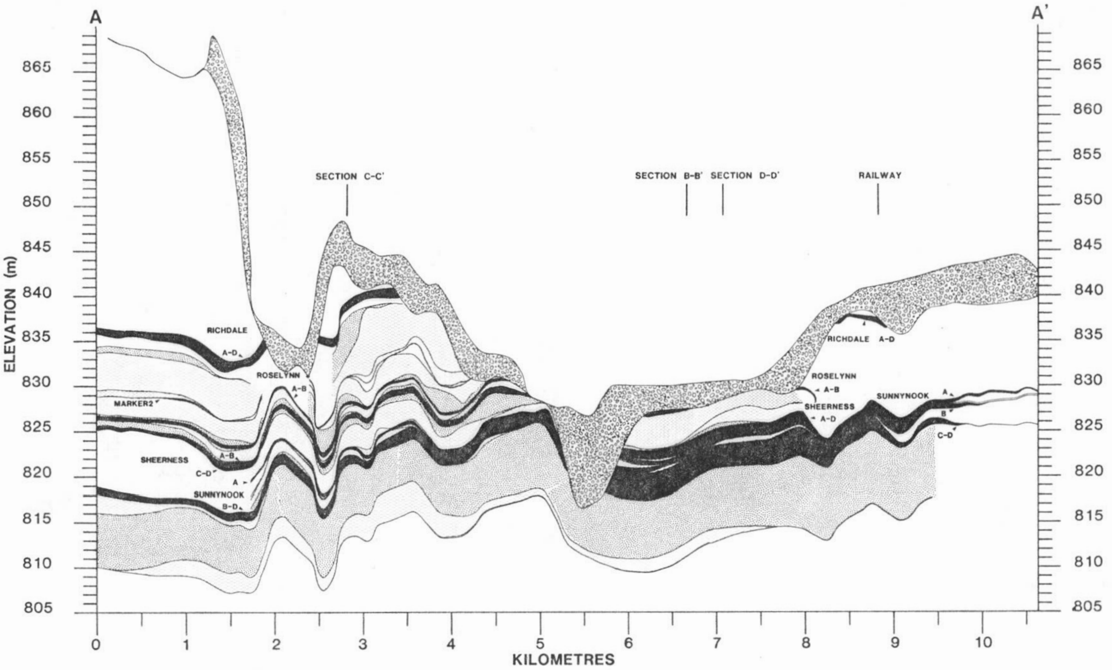
FIGURE 19b



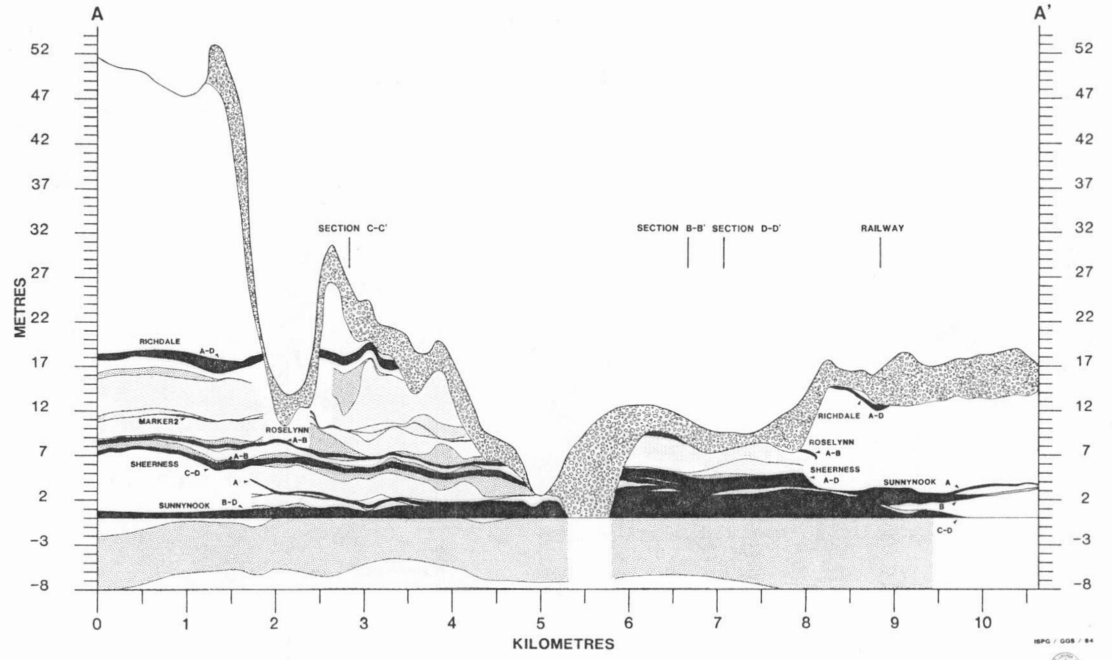
PERSPECTIVE BLOCK DIAGRAM

SUNNYNOOK "A - B" PARTING

FIGURE 20



CROSS SECTION A - A' (Sea Level Datum)



CROSS SECTION A - A' (Sunnynook Datum)

FIGURE 21

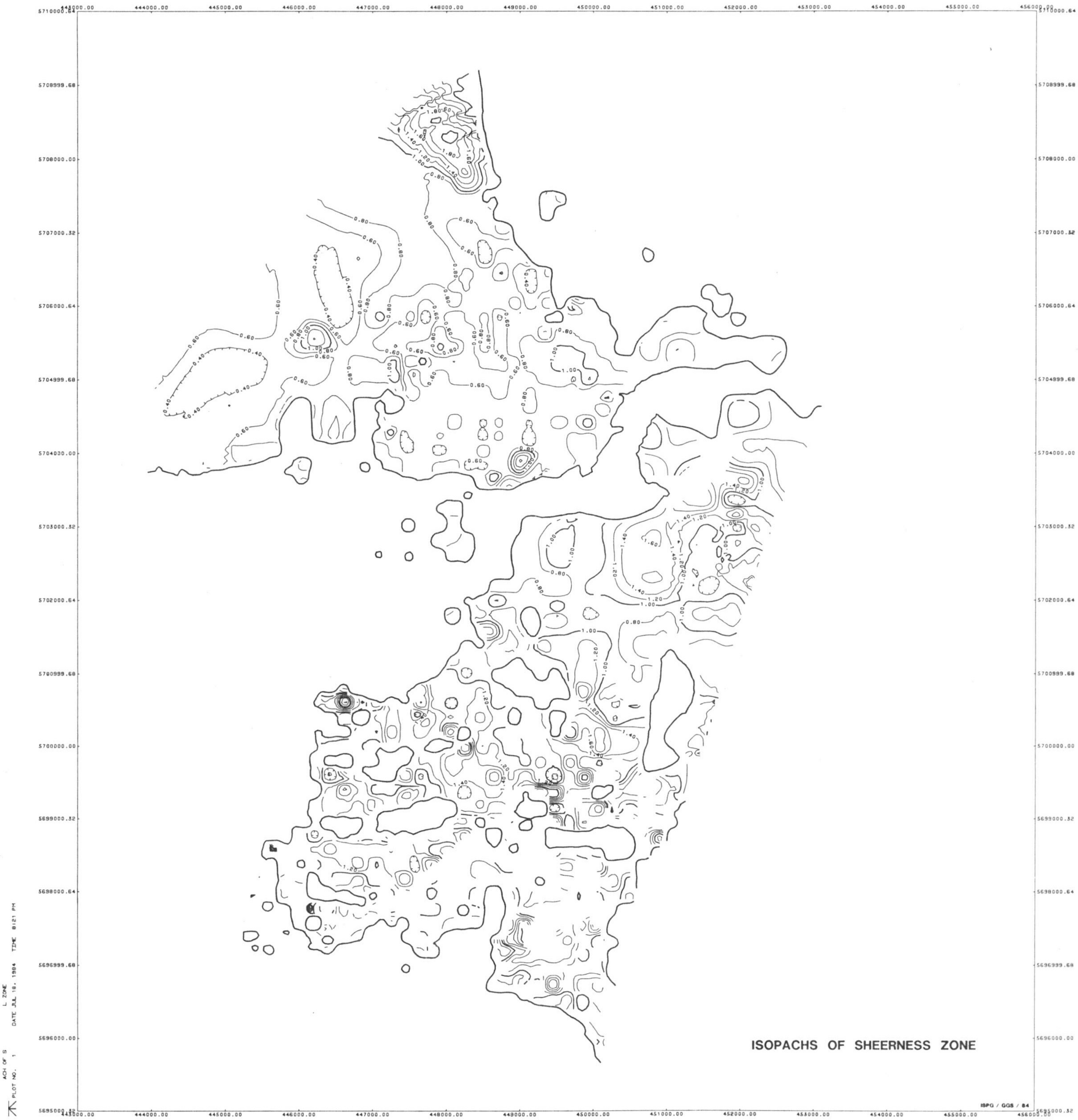
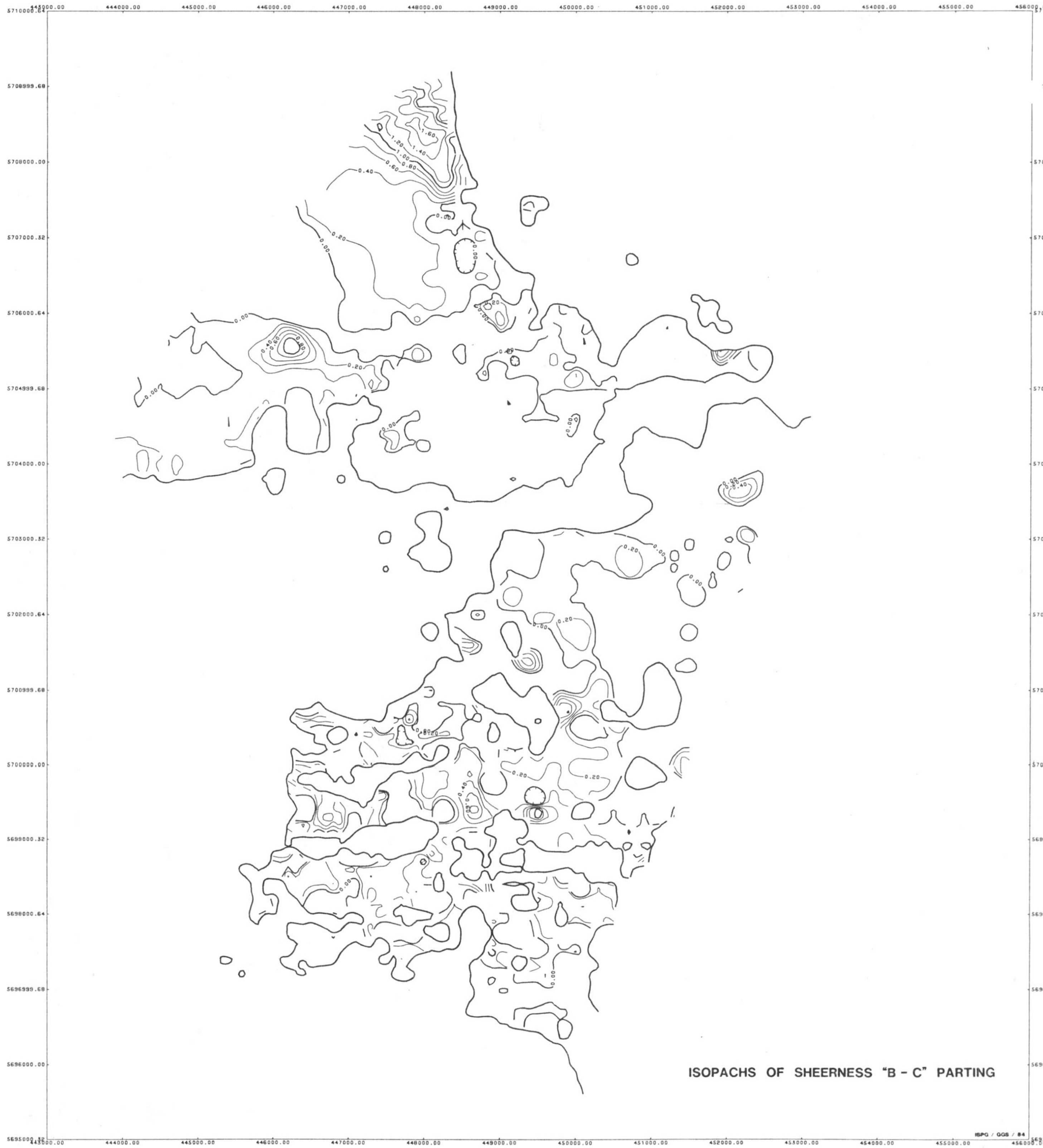
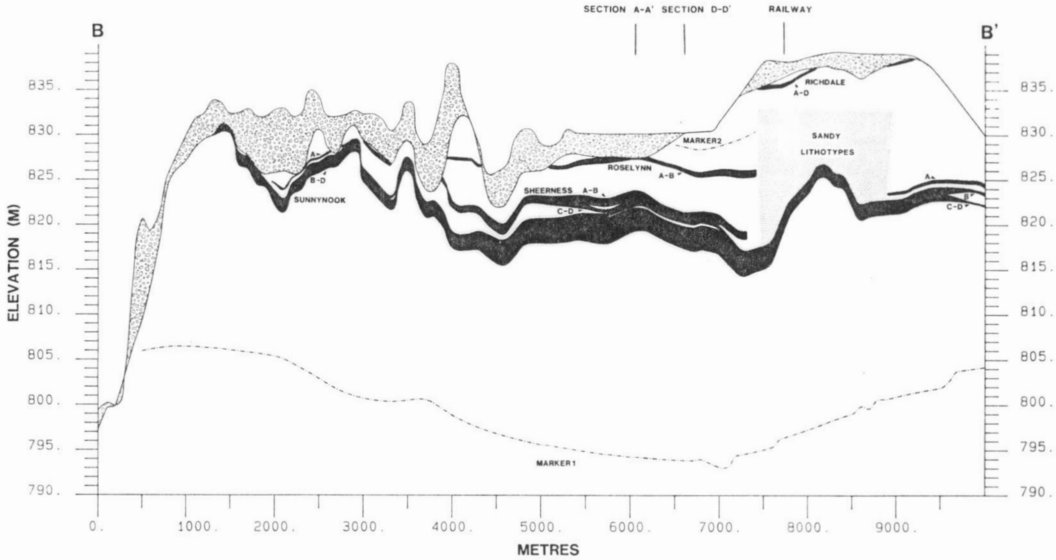

ISOPACHS OF SHEERNESS ZONE
ISPG / GGS / 84
443000.00
444000.00
445000.00
446000.00
447000.00
448000.00
449000.00
450000.00
451000.00
452000.00
453000.00
454000.00
455000.00
456000.00
5710000.64
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32

FIGURE 22

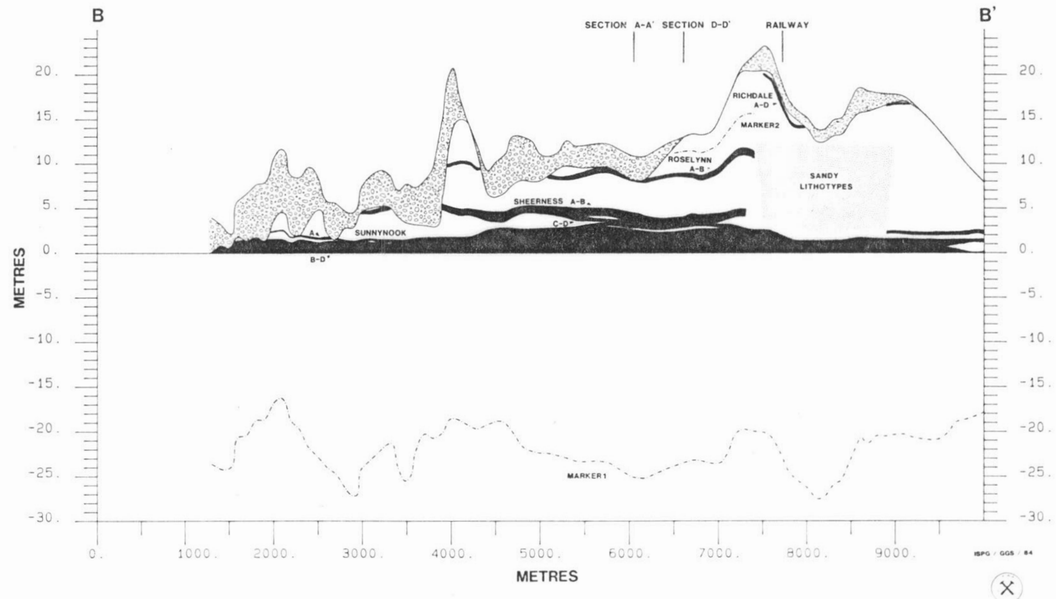


ISOPACHS OF SHEERNESS "B - C" PARTING

FIGURE 23

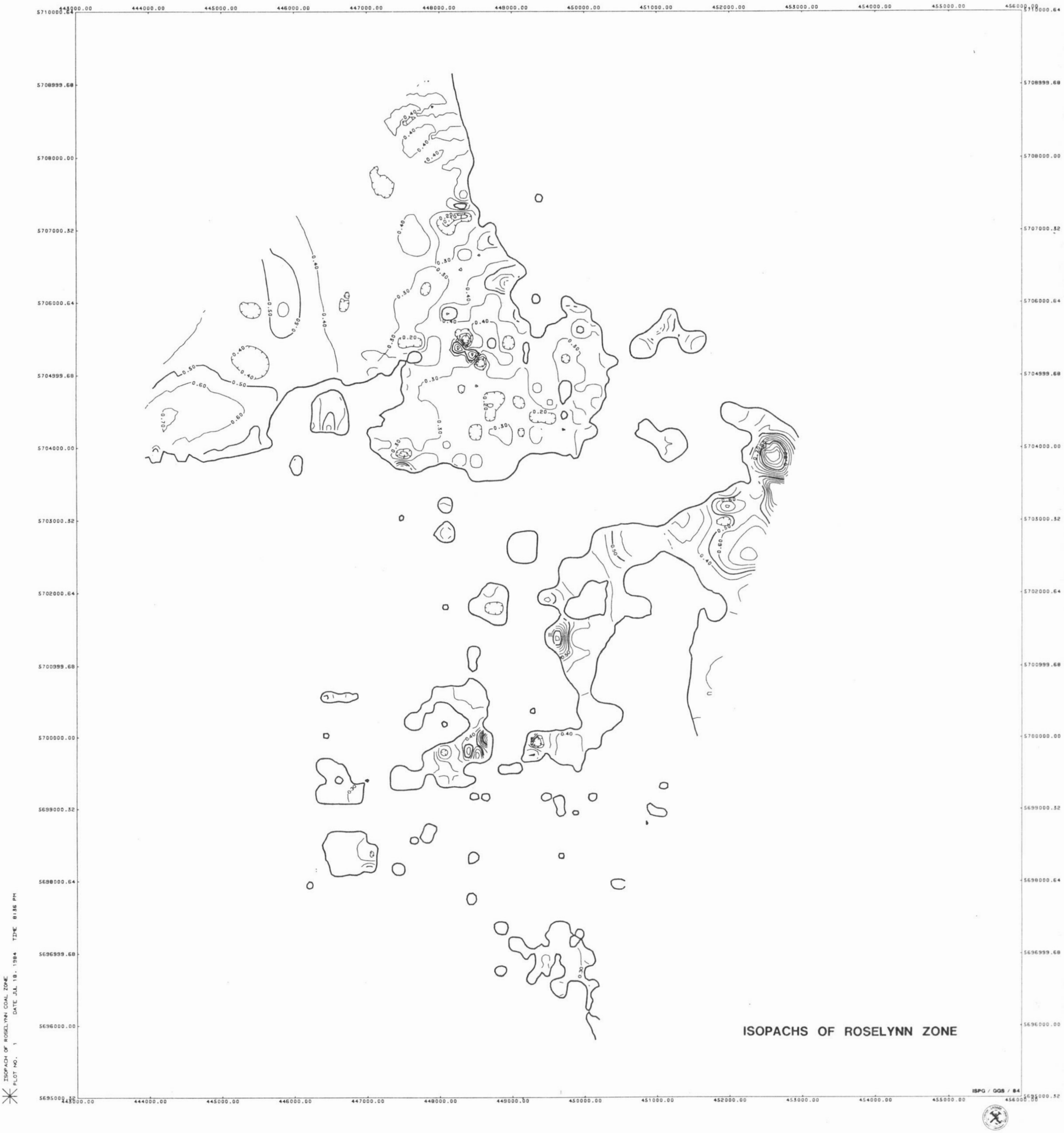


CROSS SECTION B - B' (Sea Level Datum)



CROSS SECTION B - B' (Sunnynook Datum)

FIGURE 24


ISOPACHS OF ROSELYNN ZONE
ISPG / GGS / 84
ISOPACH OF ROSELYNN COAL ZONE
PLOT NO. 1 DATE JUL 18, 1984 TIME 8:56 PM

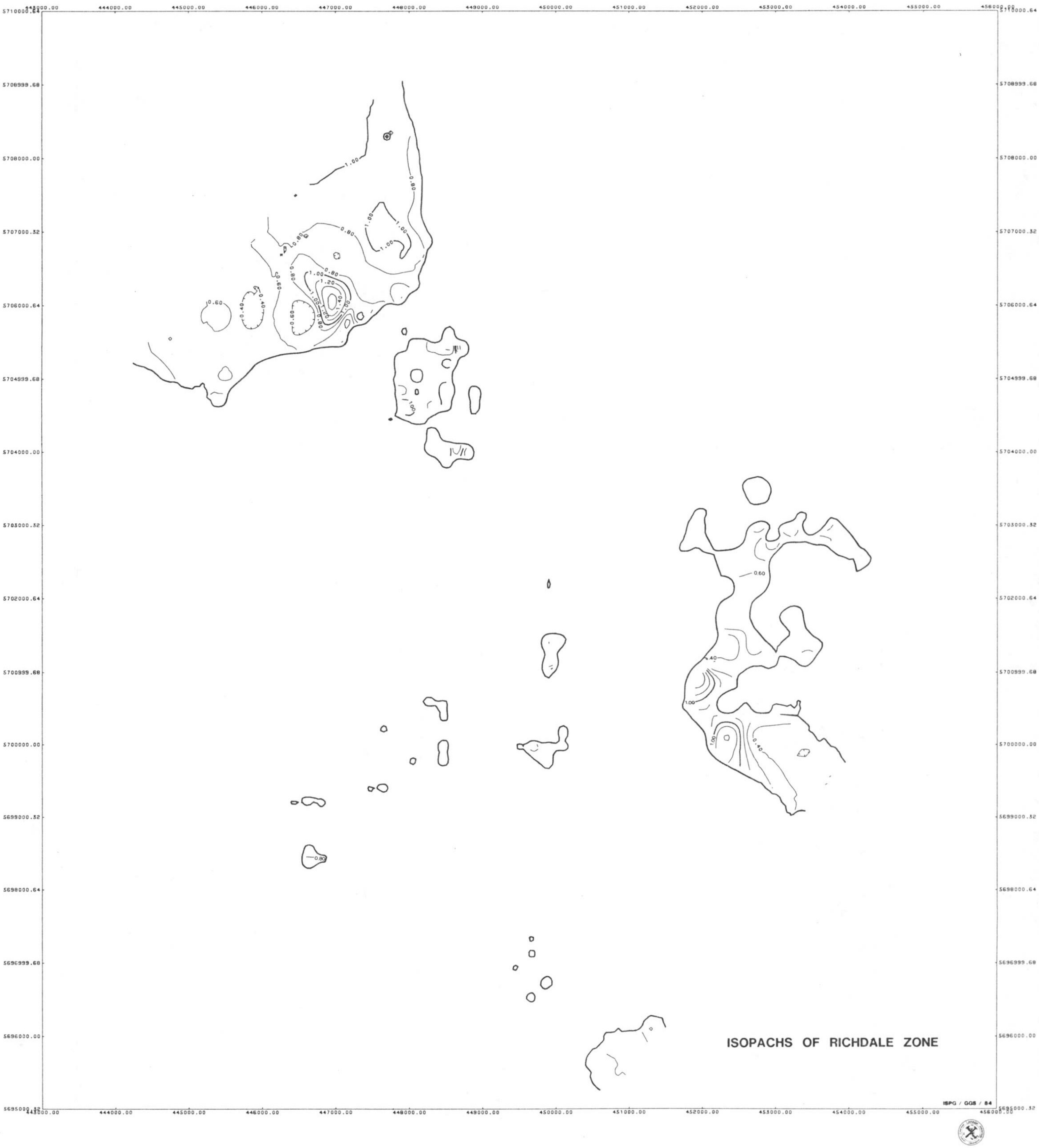
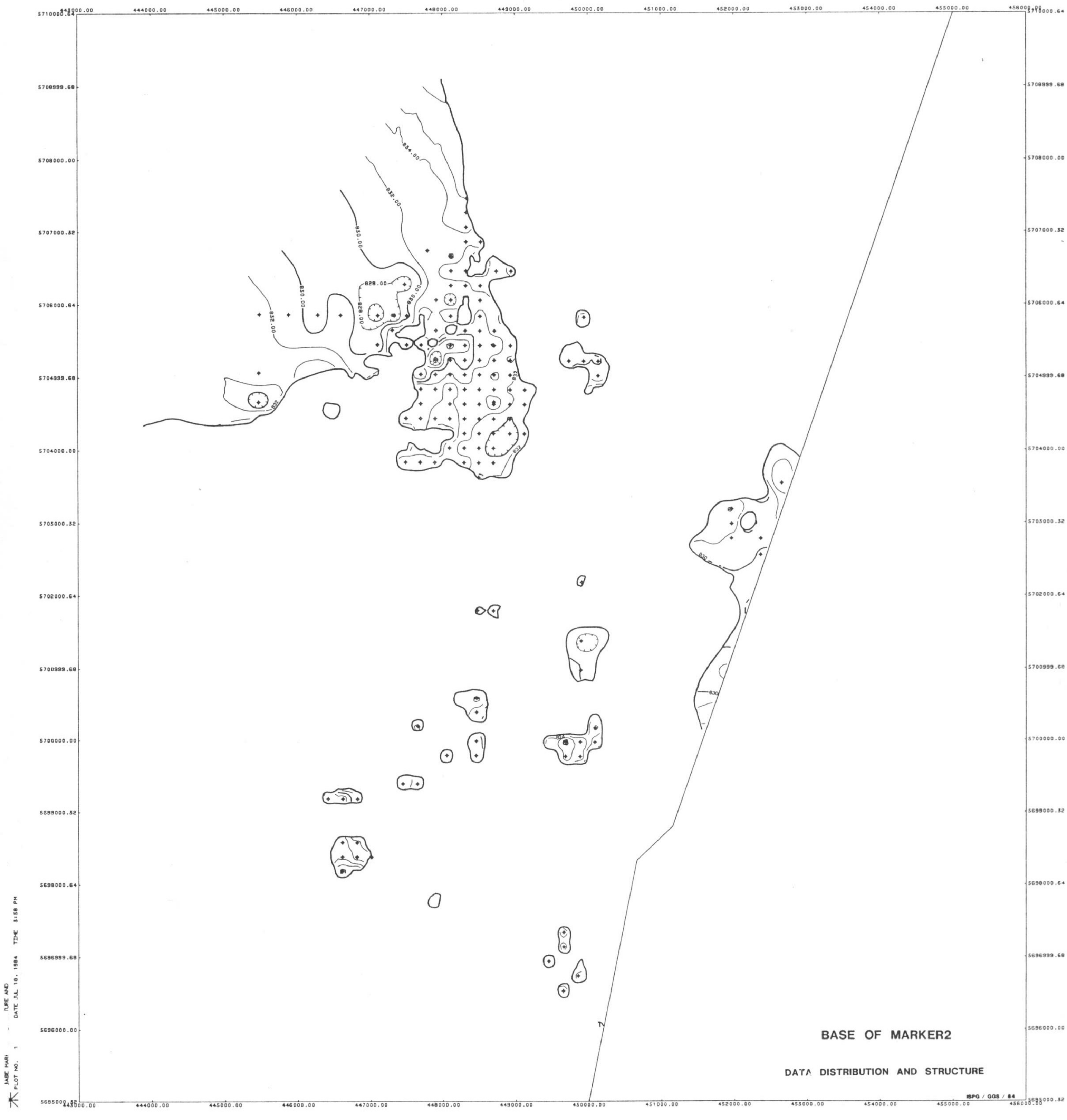

ISOPACHS OF RICHDALE ZONE
ISOPACH OF AL ZONE
PLOT NO. 1 DATE JUL 18, 1984 TIME 8:46 PM
ISPG / GGS / 84

FIGURE 26

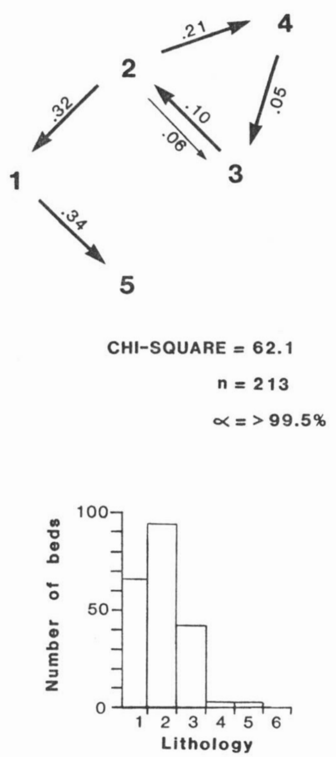

BASE OF MARKER1
DATA DISTRIBUTION AND STRUCTURE
ISPG / GGS / 84
BASE MARKER1 STRUCTURE AND DATA
PLOT NO. 1
DATE JUL 19, 1984
TIME 3:53 PM

FIGURE 27



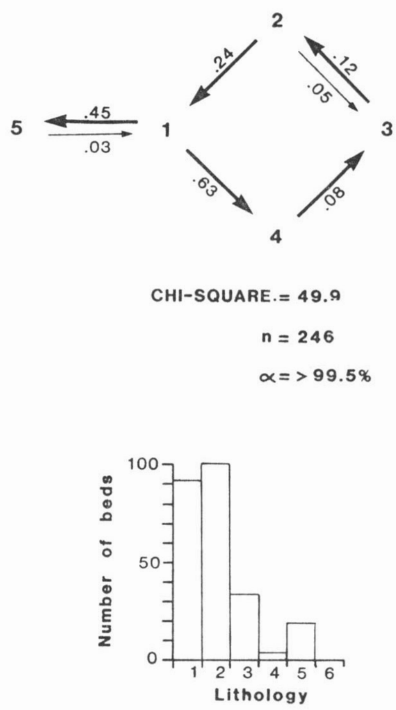
BASE OF MARKER2
DATA DISTRIBUTION AND STRUCTURE
ISPG / GGS / 84

MARKOV ANALYSES AND LITHOLOGIC COMPOSITIONS



0 TO 5 METRE INTERVAL BELOW MARKER1

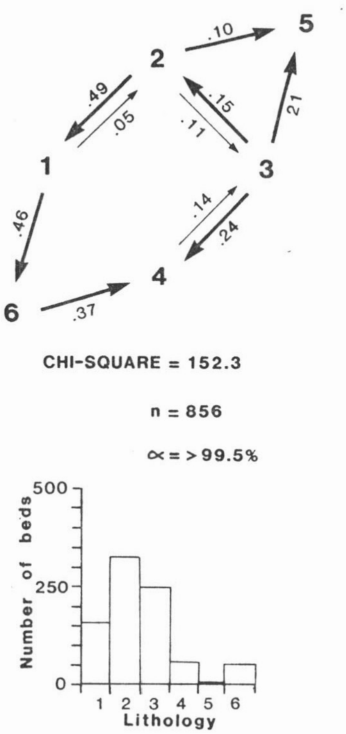
FIGURE 28a



0 TO 10 METRE INTERVAL BELOW MARKER1

FIGURE 28b

MARKOV ANALYSIS AND LITHOLOGIC COMPOSITION



INTERVAL BETWEEN MARKER1 AND SUNNYNOOK ZONE

FIGURE 29

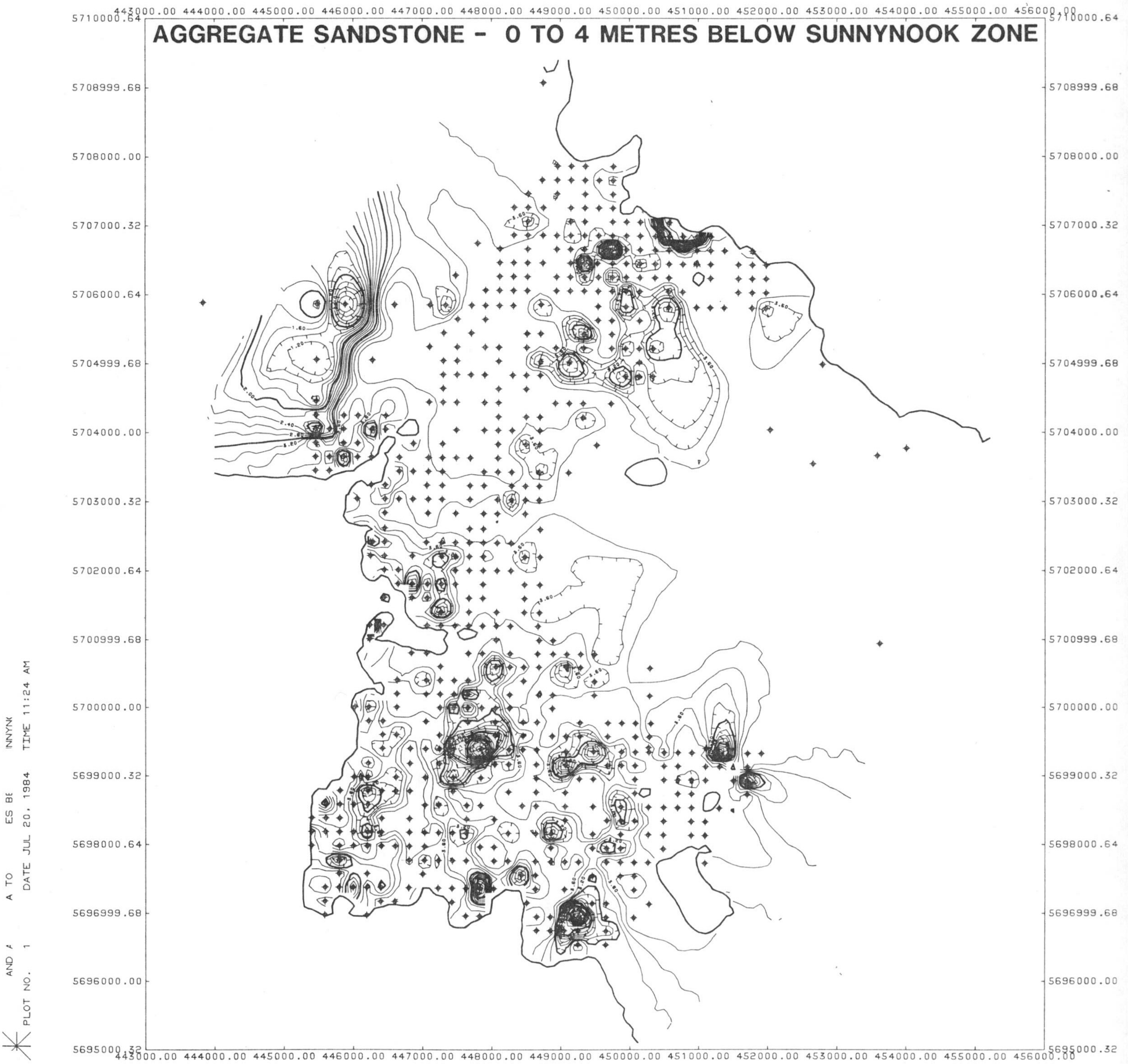

AGGREGATE SANDSTONE - 0 TO 4 METRES BELOW SUNNYNOOK ZONE
443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
5710000.64
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
PLOT NO. 1
DATE JUL 20, 1984
TIME 11:24 AM

FIGURE 30

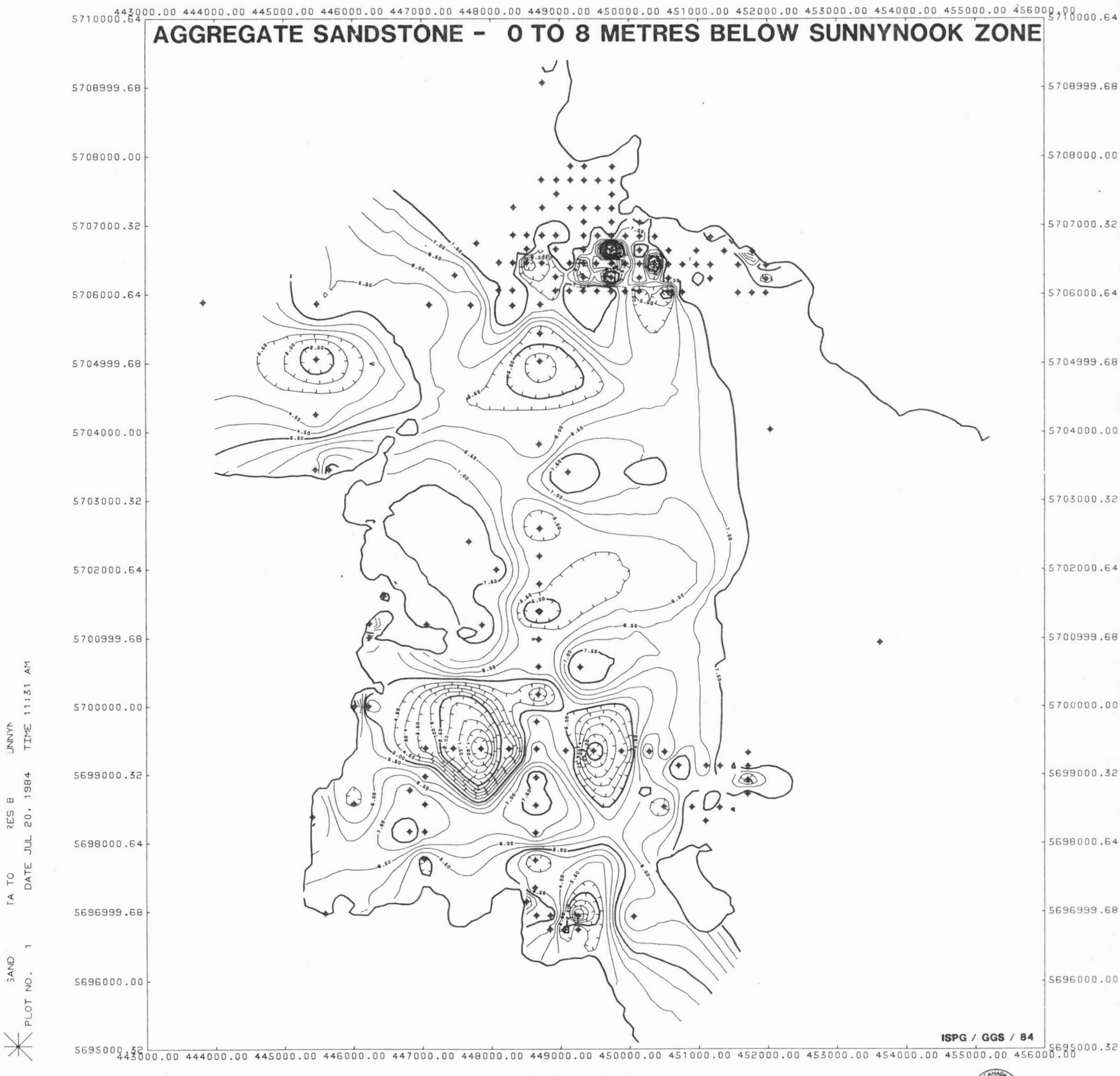

AGGREGATE SANDSTONE - 0 TO 8 METRES BELOW SUNNYNOOK ZONE
443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
5710000.64
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
ISPG / GGS / 84
PLOT NO. 1
DATE JUL 20, 1984 TIME 11:31 AM

FIGURE 31

ISOLITHS - SUNNYNOOK "B - C" PARTING

(FIGS. 32a-c)

FIGURE 32a

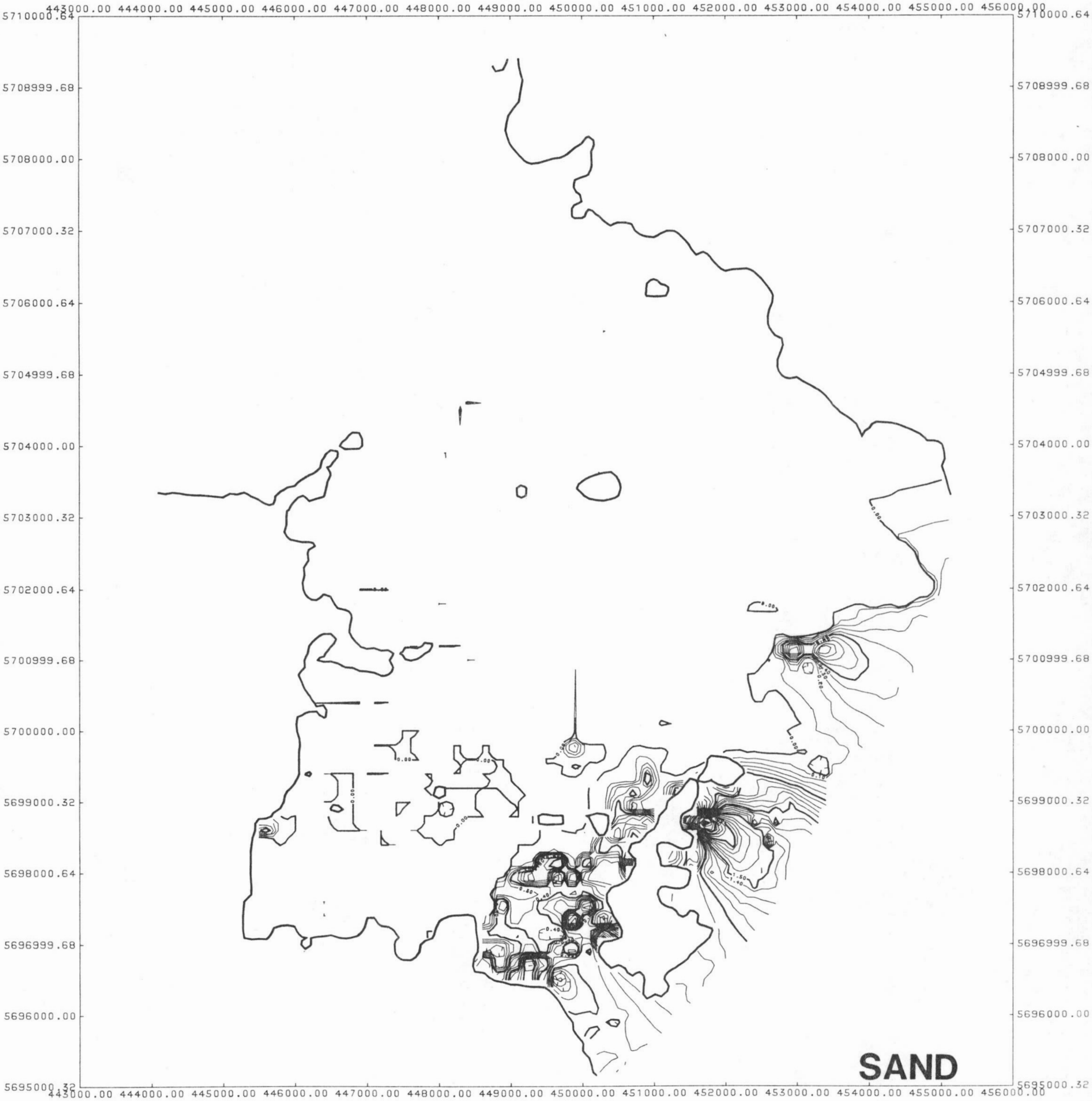
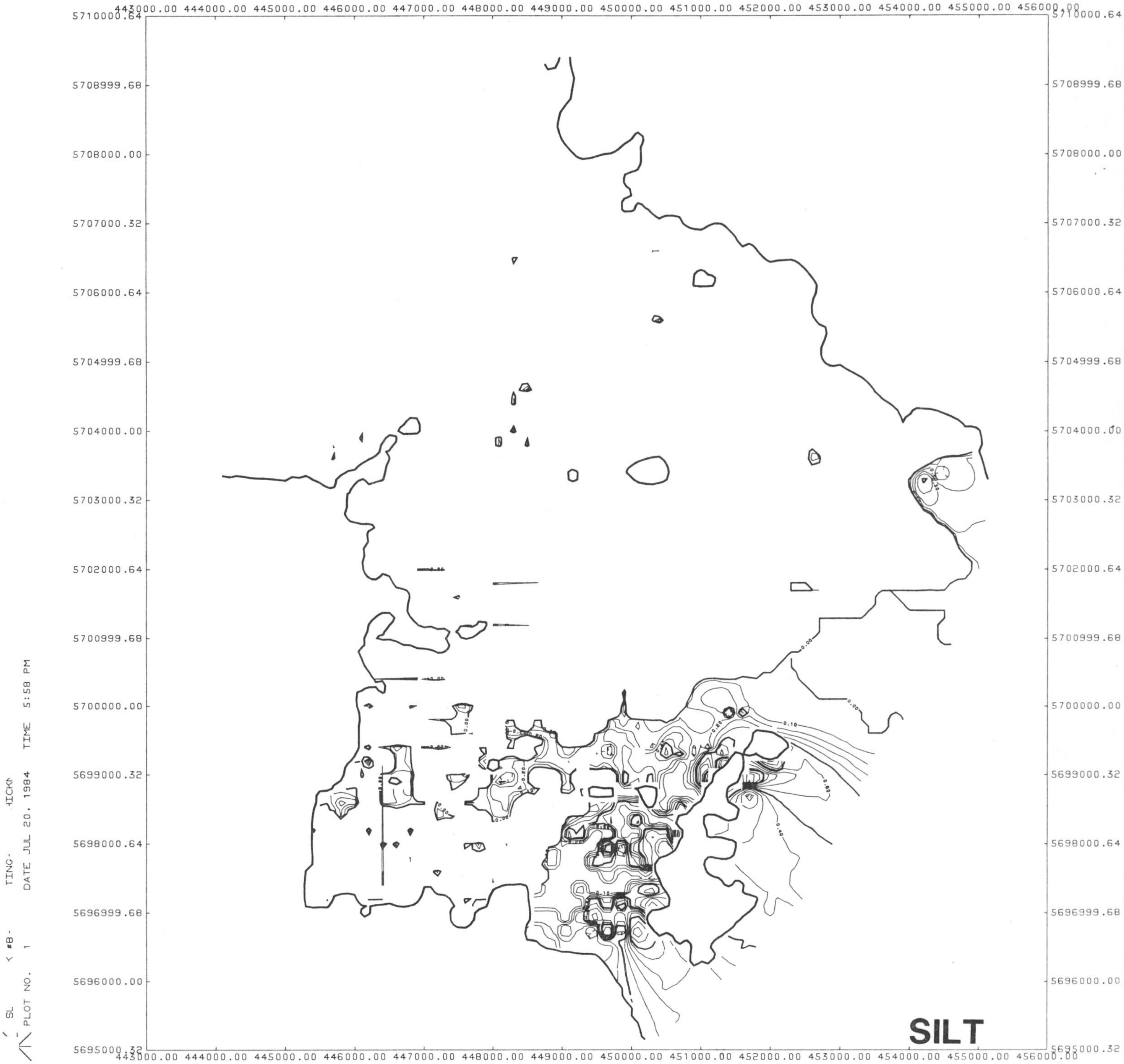


FIGURE 32b



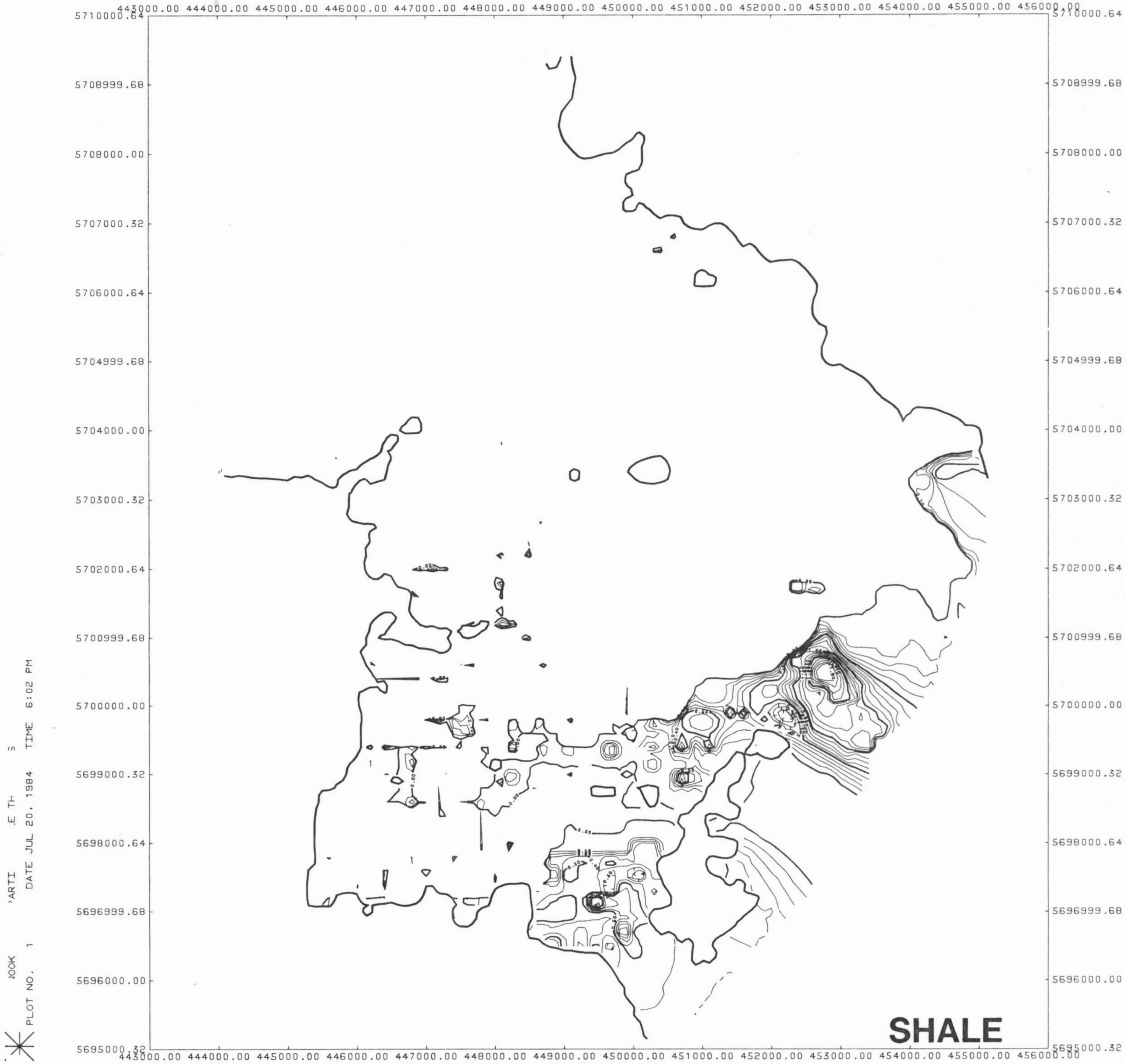
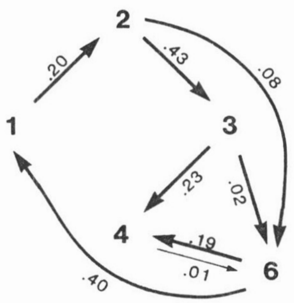

443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
5710000.64
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
SHALE
PLOT NO. 1
DATE JUL 20, 1984 TIME 6:02 PM

FIGURE 32c

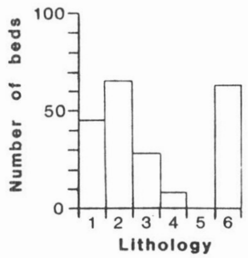
MARKOV ANALYSIS AND LITHOLOGIC COMPOSITION



CHI-SQUARE = 21.1

n = 213

α = > 85%



SUNNYNOOK "B - C" PARTING

FIGURE 33

ISOLITHS - SUNNYNOOK "A - B" PARTING
(FIGS. 34a-c, 35)

FIGURE 34a

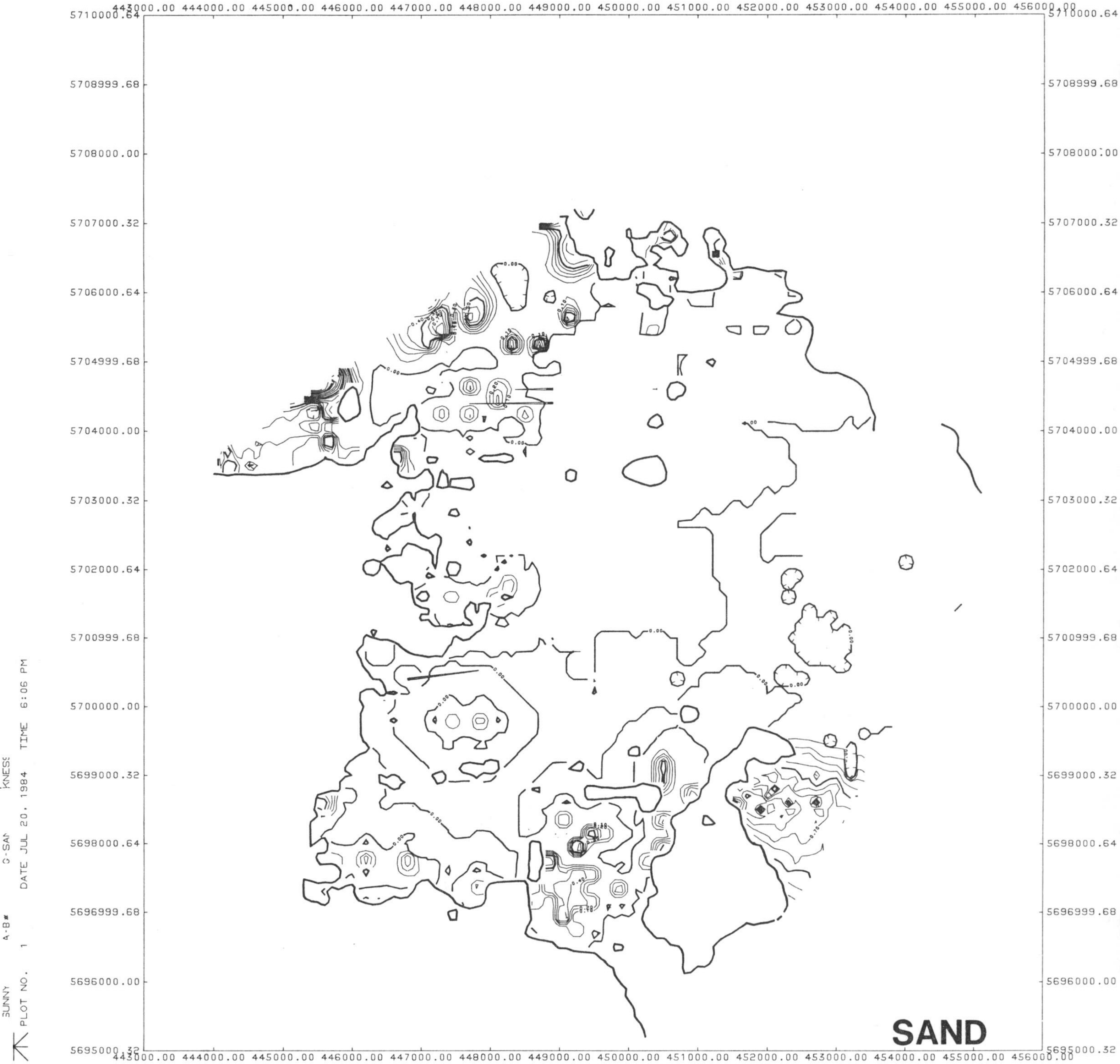
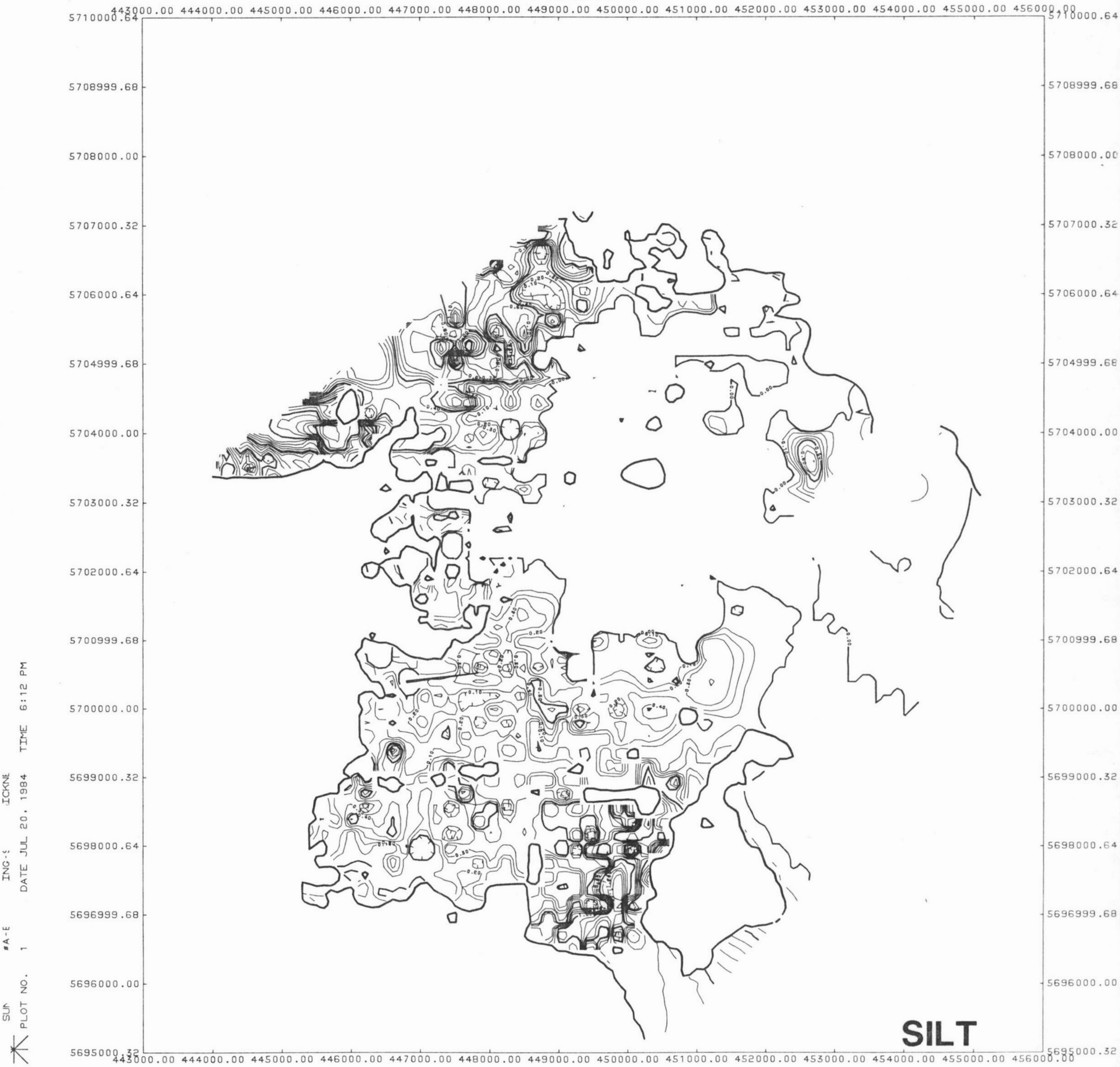


FIGURE 34b


443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
5710000.64
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
SILT
PLOT NO. 1
DATE JUL 20, 1984
TIME 6:12 PM

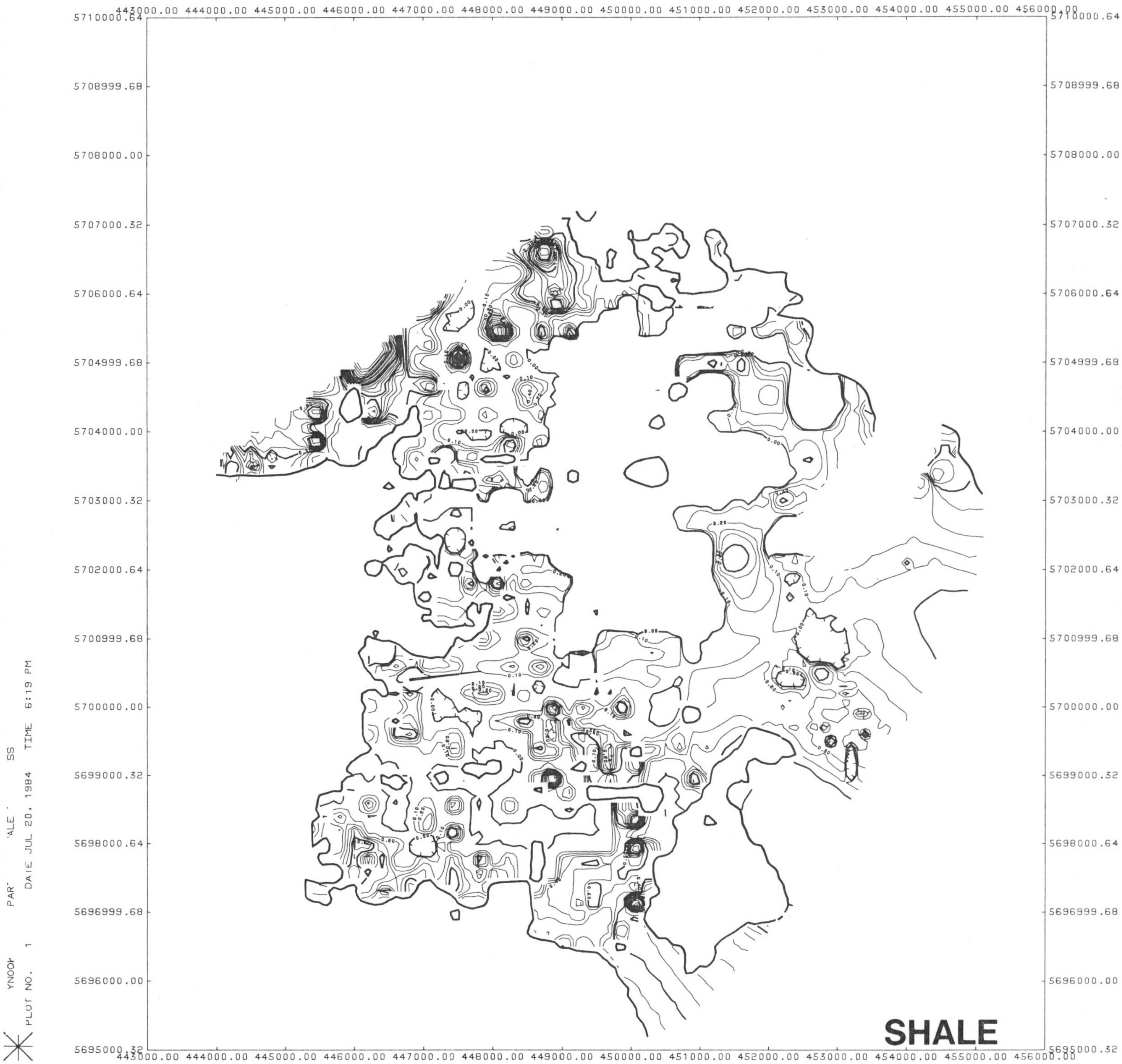
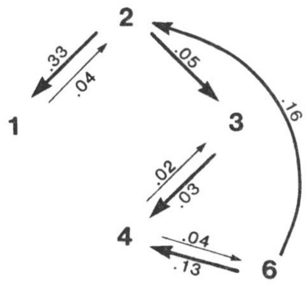

SHALE
443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
5710000.64
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
PLOT NO. 1 DATE JUL 20, 1984 TIME 6:19 PM

FIGURE 34c

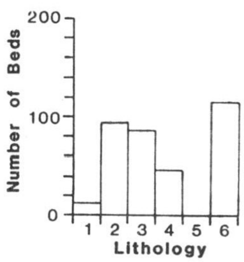
MARKOV ANALYSIS AND LITHOLOGIC COMPOSITION



CHI-SQUARE = 24.0

n = 353

α = > 90%

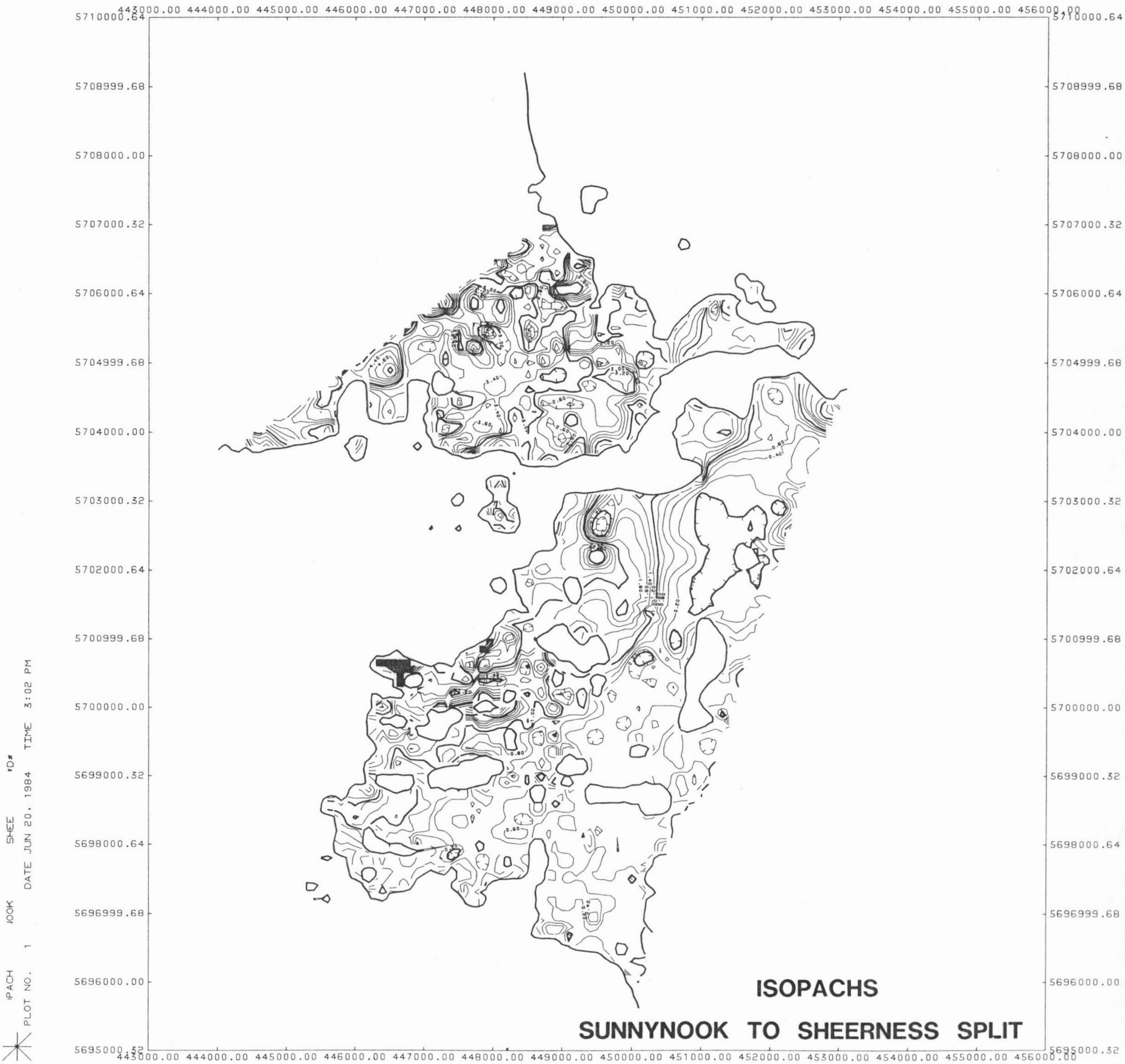


SUNNYNOOK "A-B" PARTING

FIGURE 35

ISPG / GGS / 84

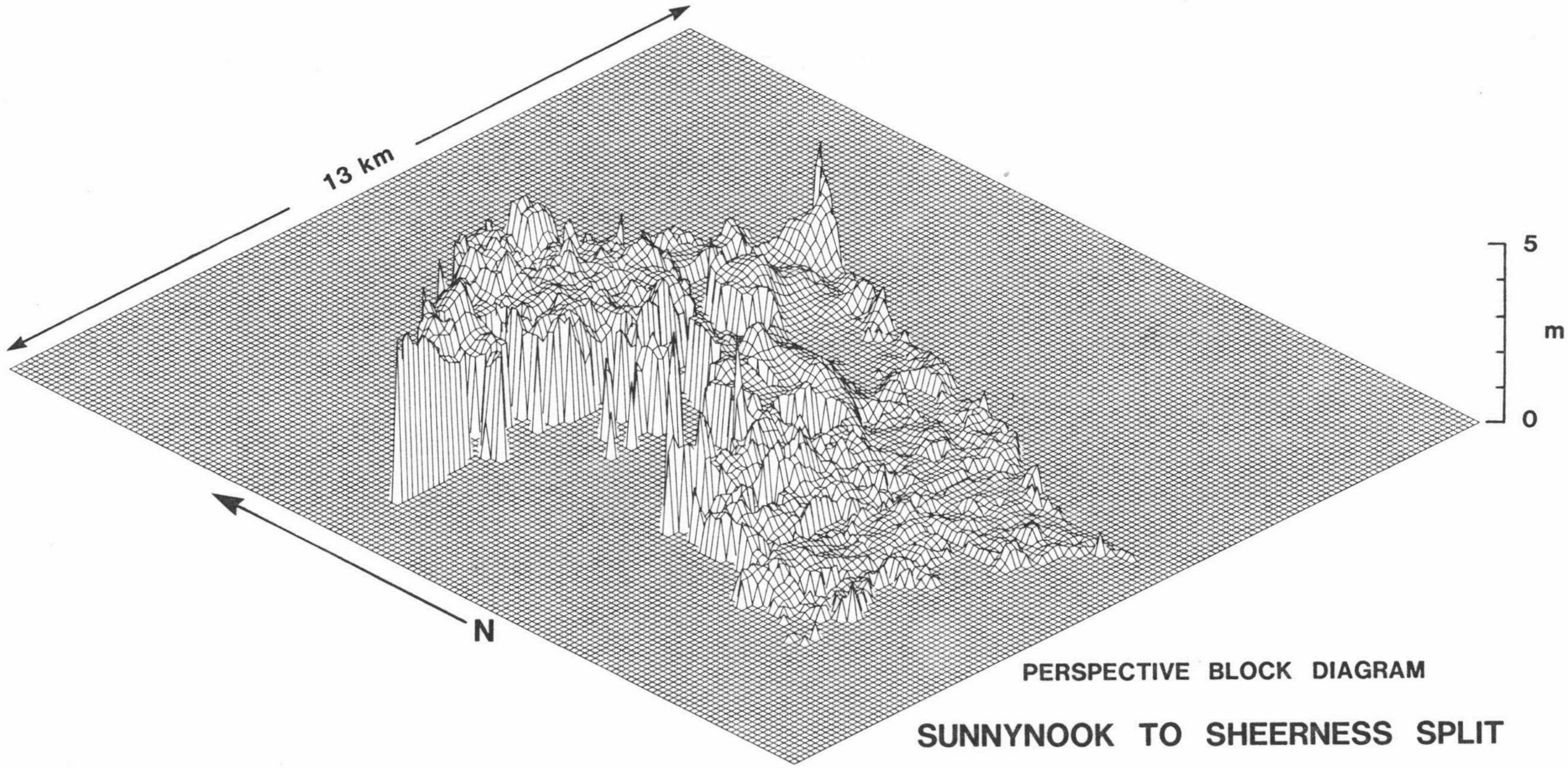
FIGURE 36a



ISOPACHS

SUNNYNOOK TO SHEERNESS SPLIT

FIGURE 36b



PERSPECTIVE BLOCK DIAGRAM

SUNNYNOOK TO SHEERNESS SPLIT

ISOLITHS - SUNNYNOOK TO SHEERNESS SPLIT

(FIGS. 37a-c)

FIGURE 37a

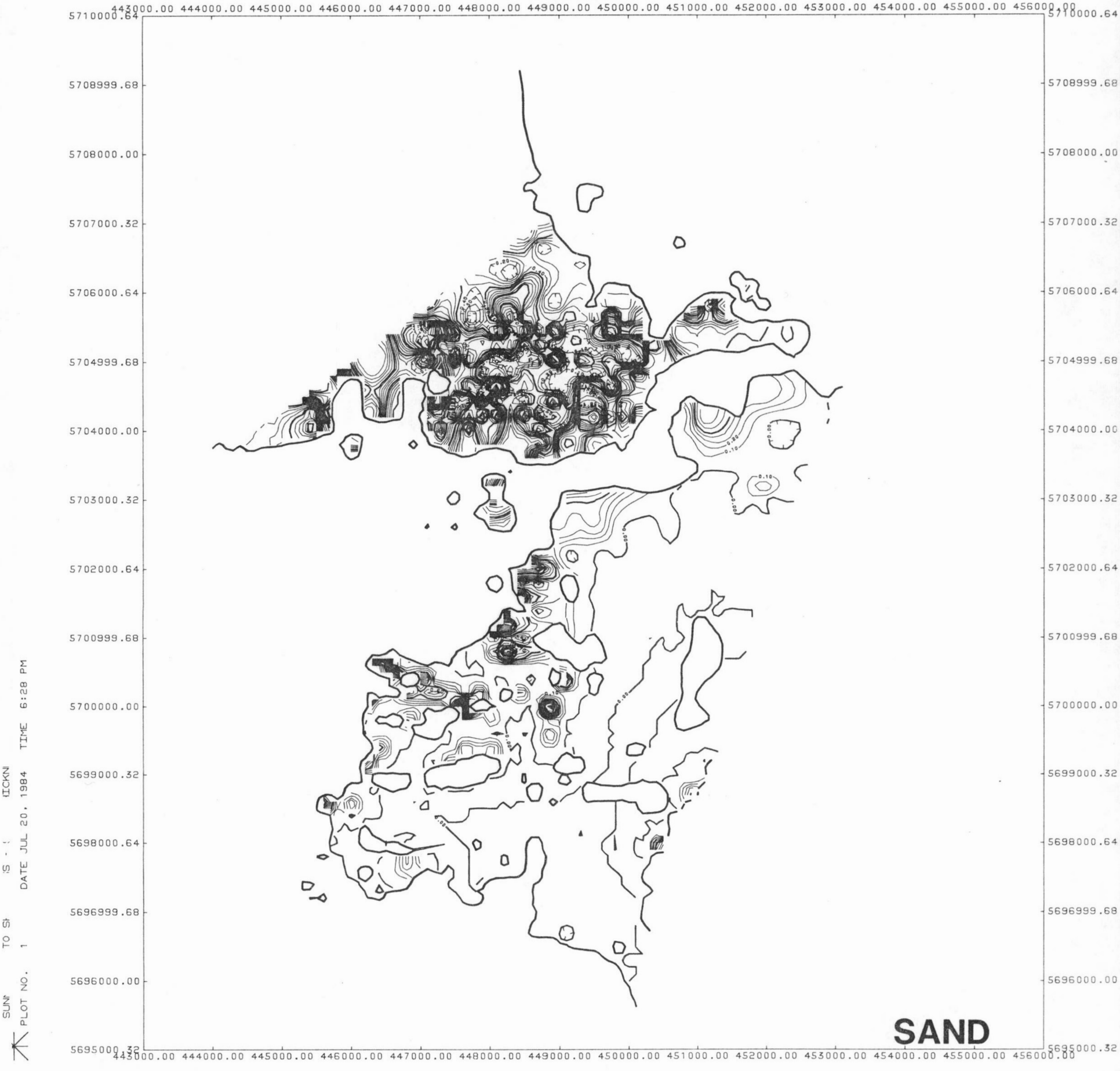
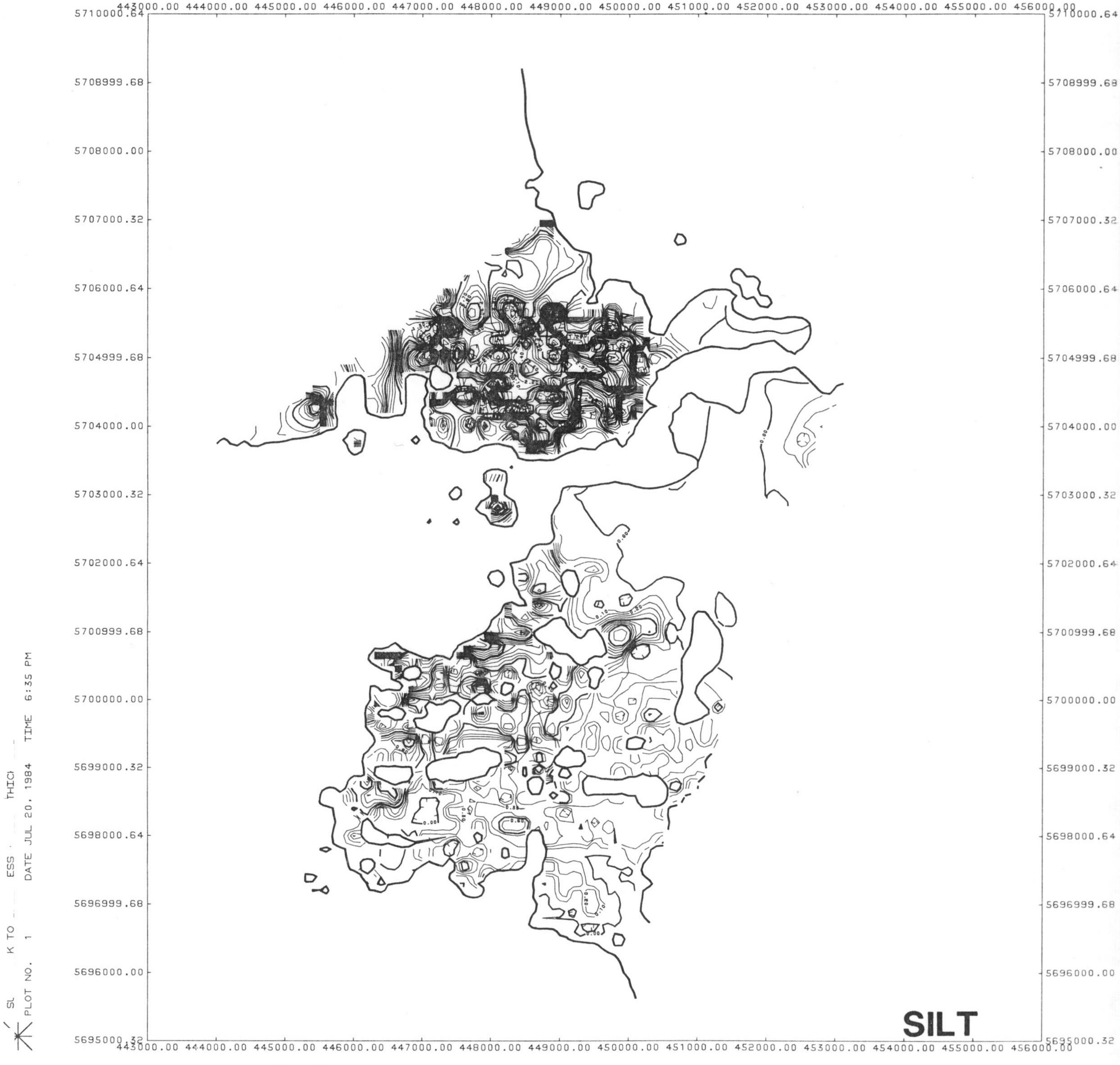


FIGURE 37b


443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
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5708999.68
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5706000.64
5704999.68
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5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
SILT
SL K TO ESS THICK
PLOT NO. 1 DATE JUL 20, 1984 TIME 6:35 PM

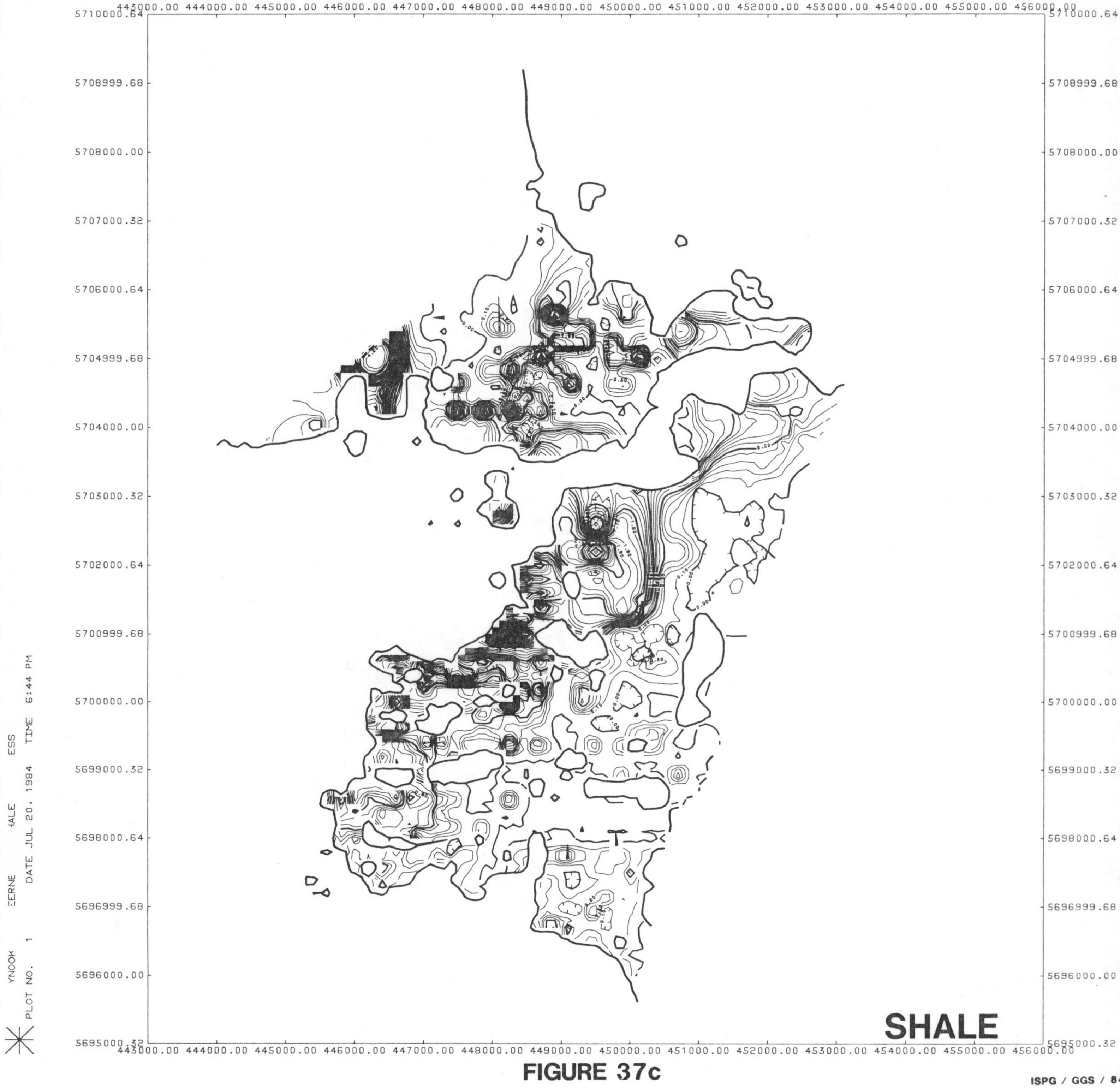


FIGURE 37c

ISPG / GGS / 84

ROCK SPLIT BETWEEN SUNNYNOOK AND SHEERNESS COAL ZONES

(FIGS. 38a-c)

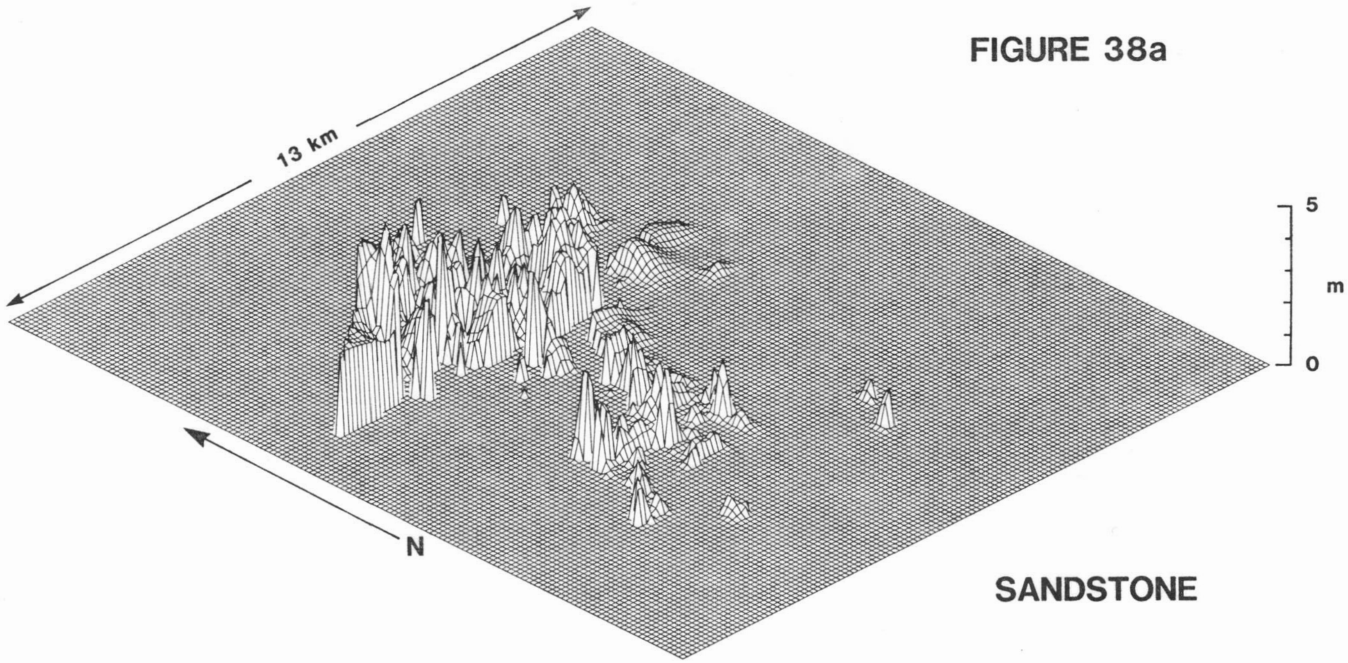


FIGURE 38a

SANDSTONE

...... SURFACE GRAPHICS SYSTEM ......
PLOT NO. 1 DATE OCT 8, 1984 TIME 8:37 PM
AZIM = 315.0 ELEV = 30.0 DIST = 200

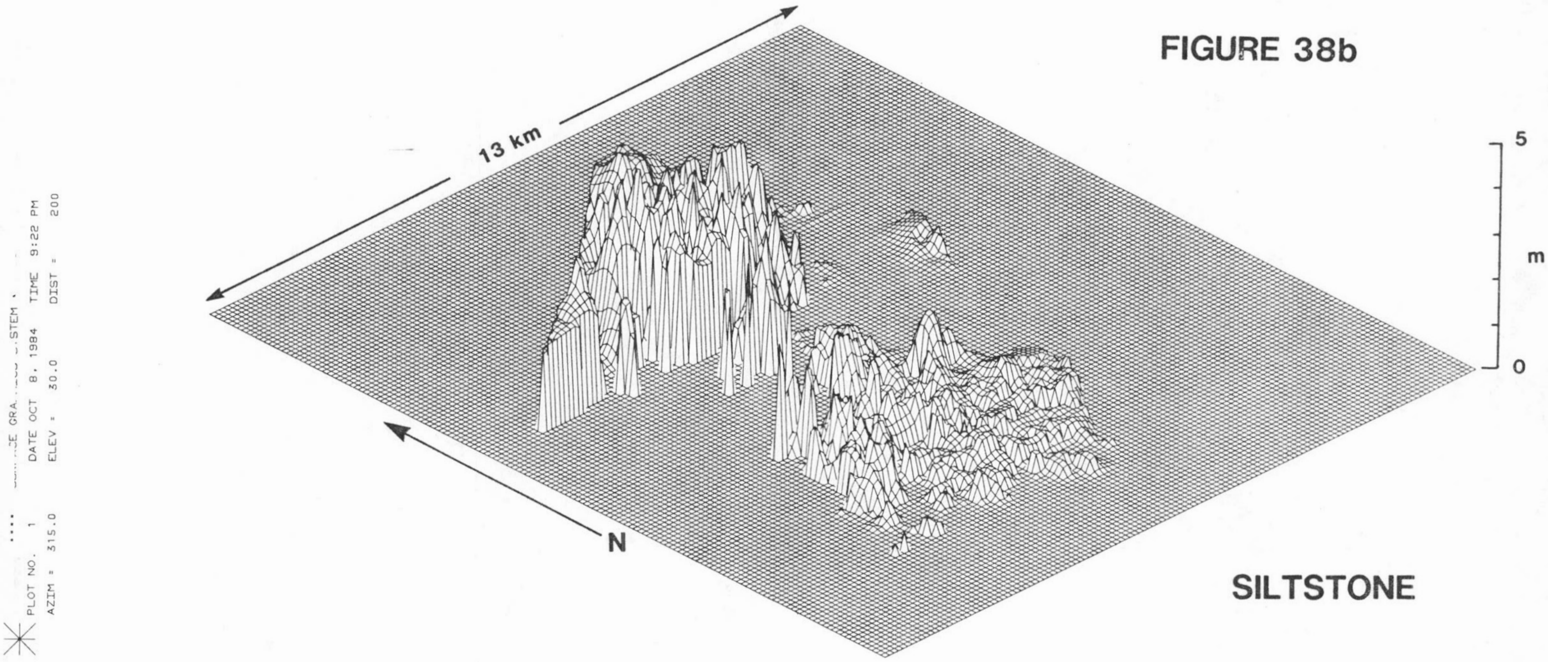


FIGURE 38b

SILTSTONE

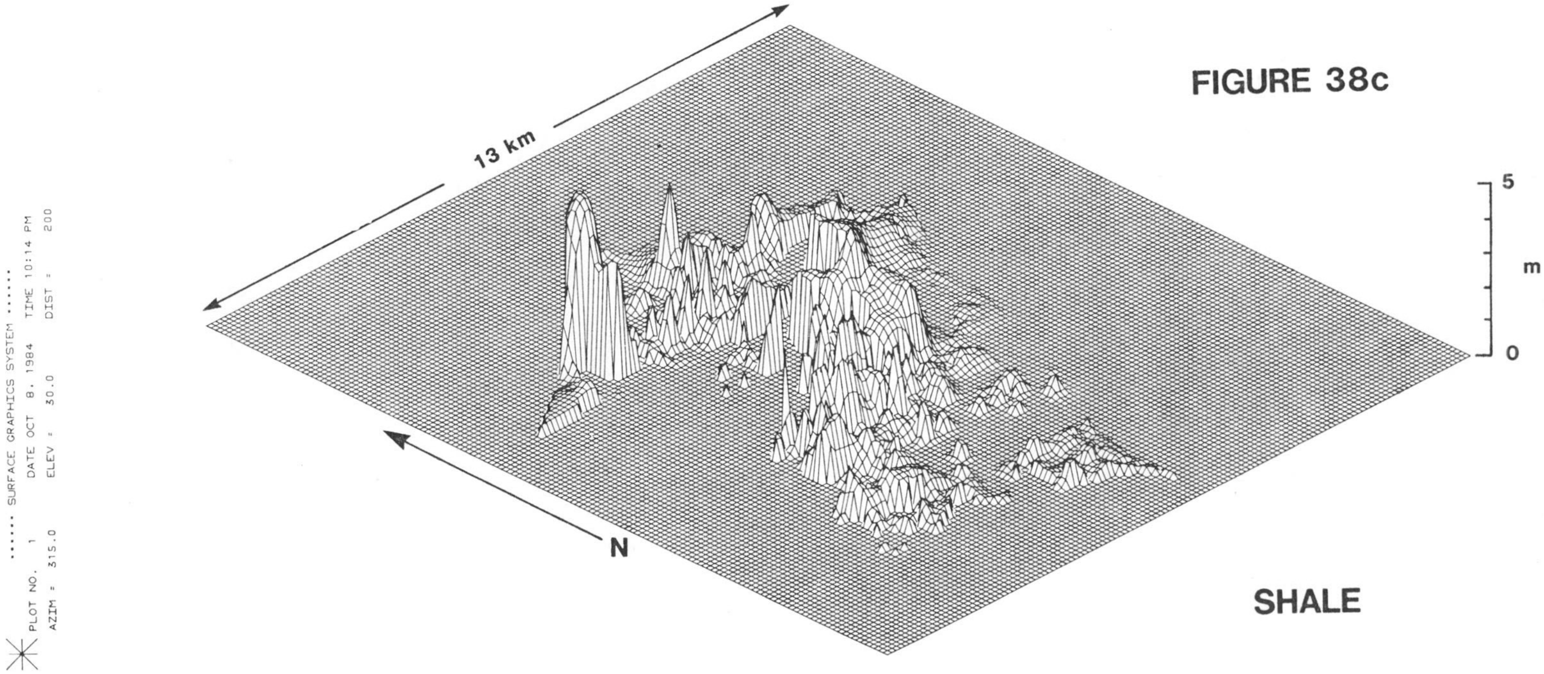
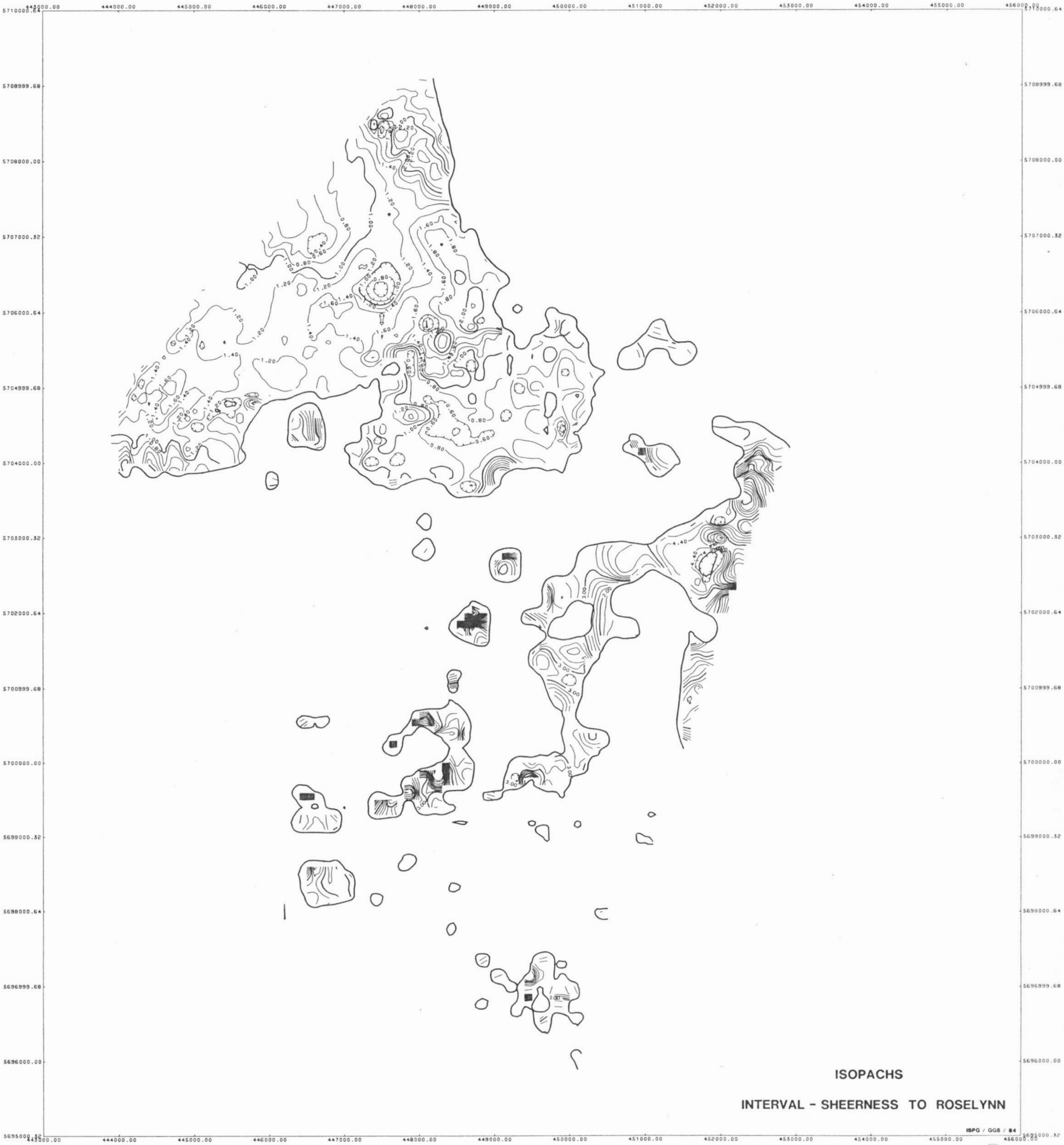


FIGURE 38c

SHALE

FIGURE 39



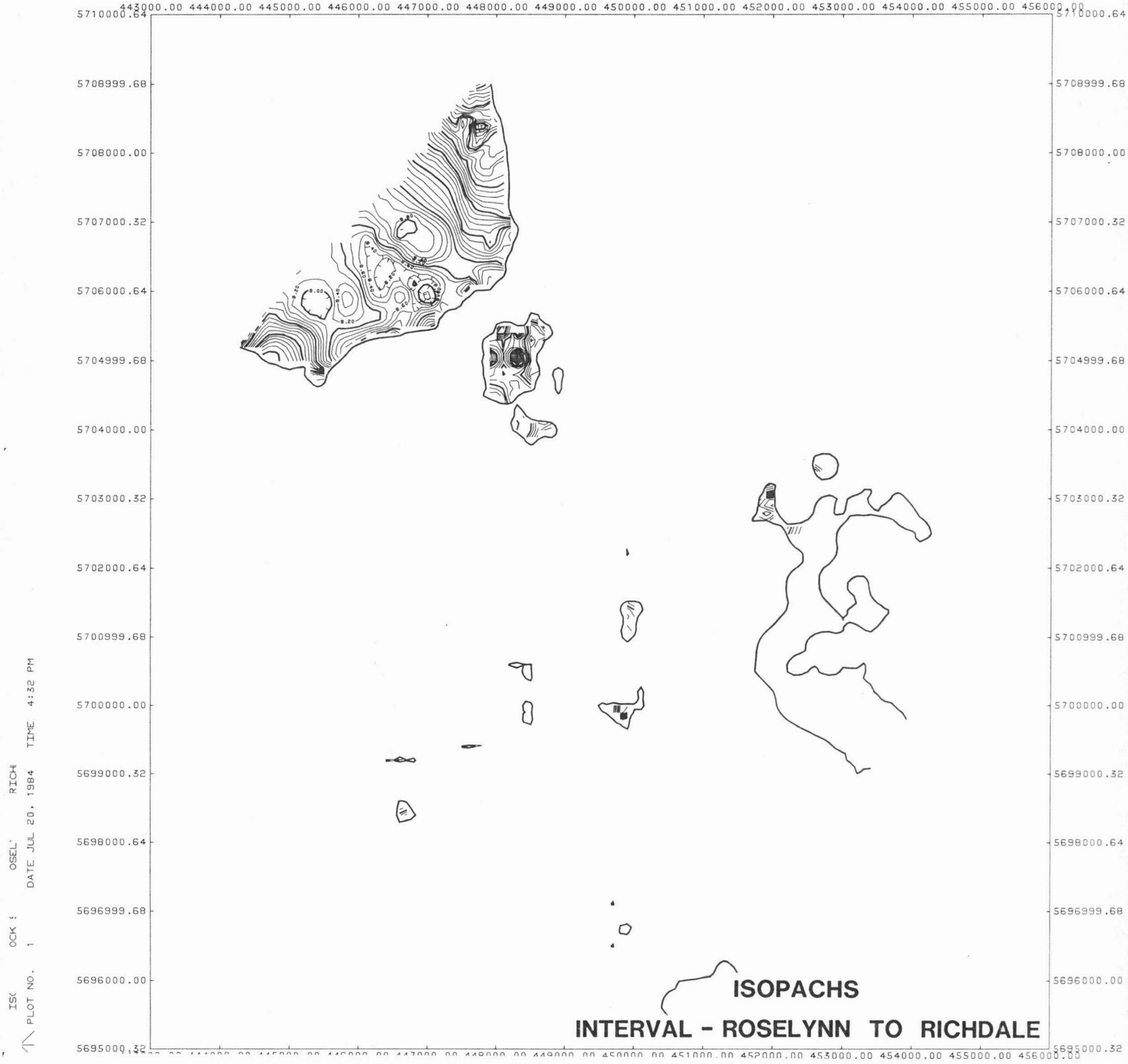
ISOPACHS

INTERVAL - SHEERNESS TO ROSELYNN

ISPG / GGS / 84

ISOPACH ROCK SPLIT SHEERNESS TO ROSELYNN
PLOT NO. 1 DATE JUL 25, 1984 TIME 10:50 AM

FIGURE 41


443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
5710000.64
5708999.68
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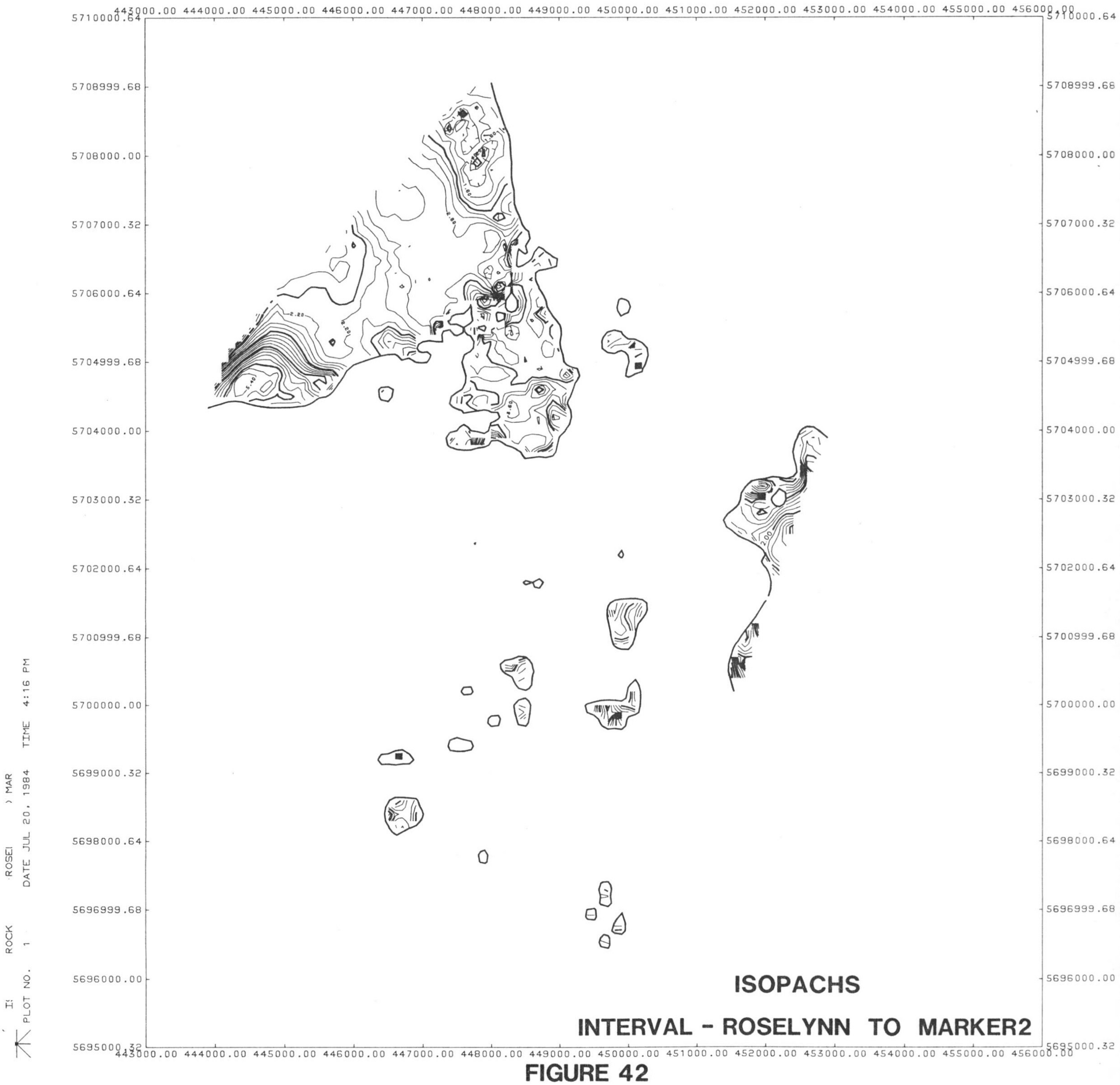
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
ISOPACHS
INTERVAL - ROSELYNN TO RICHDALE
DATE JUL 20, 1984 TIME 4:32 PM
PLOT NO. 1



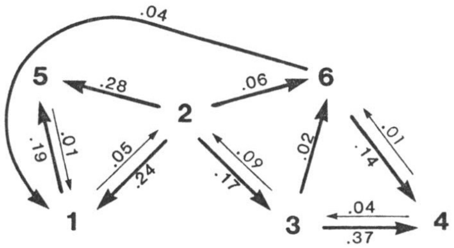
ISOPACHS

INTERVAL - ROSELYNN TO MARKER2

FIGURE 42

FIGURE 43

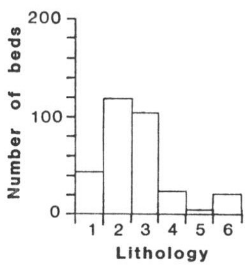
MARKOV ANALYSIS AND LITHOLOGIC COMPOSITION



CHI-SQUARE = 50.8

n = 314

α = >99.5%



INTERVAL BETWEEN ROSELYNN ZONE AND MARKER2

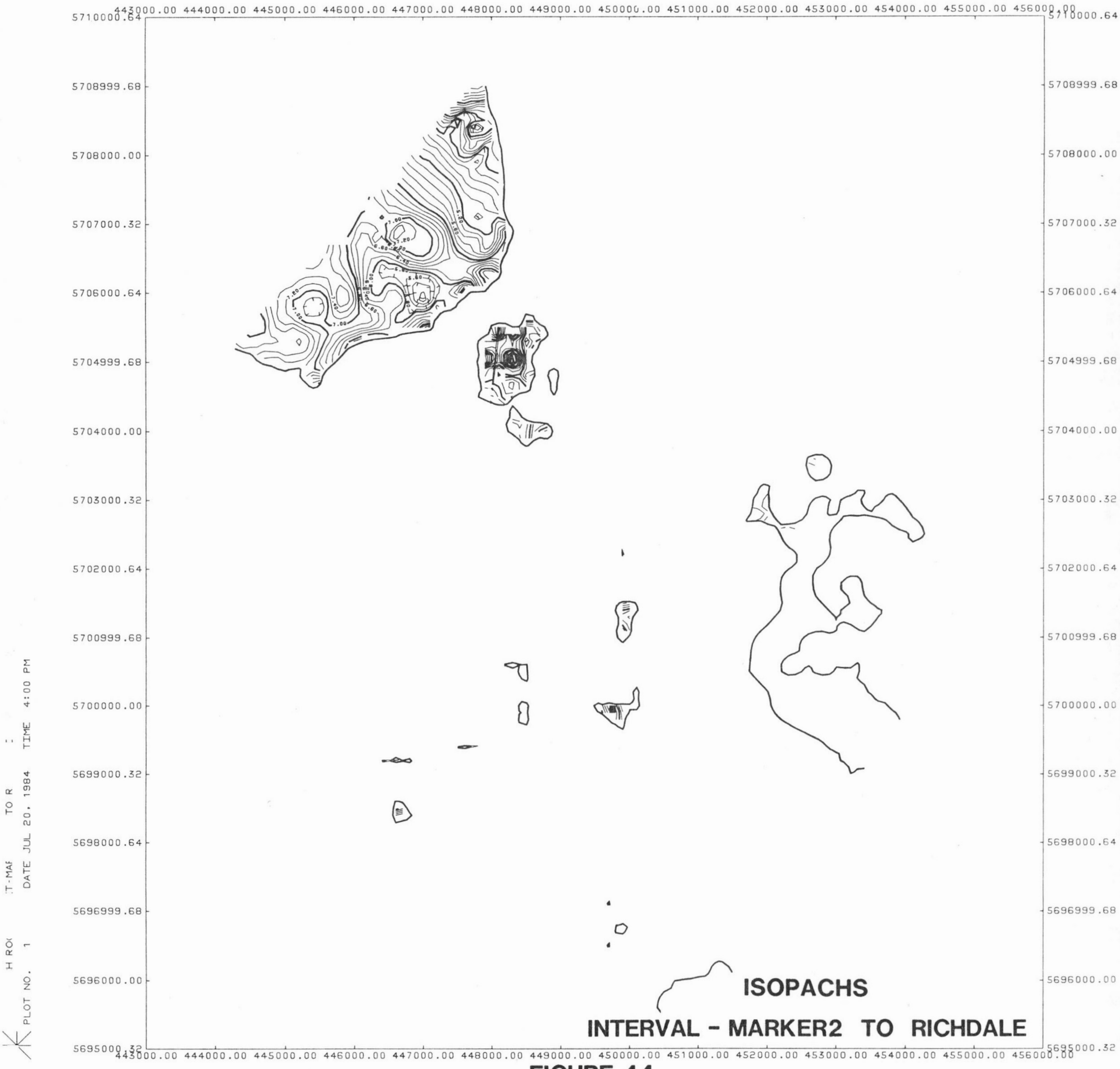
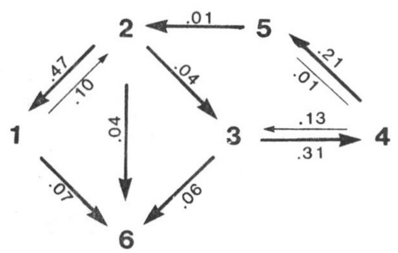


FIGURE 44

ISPG / GGS / 84

FIGURE 45

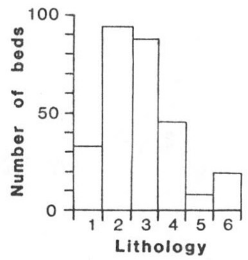
MARKOV ANALYSIS AND LITHOLOGIC COMPOSITION



CHI-SQUARE = 26.5

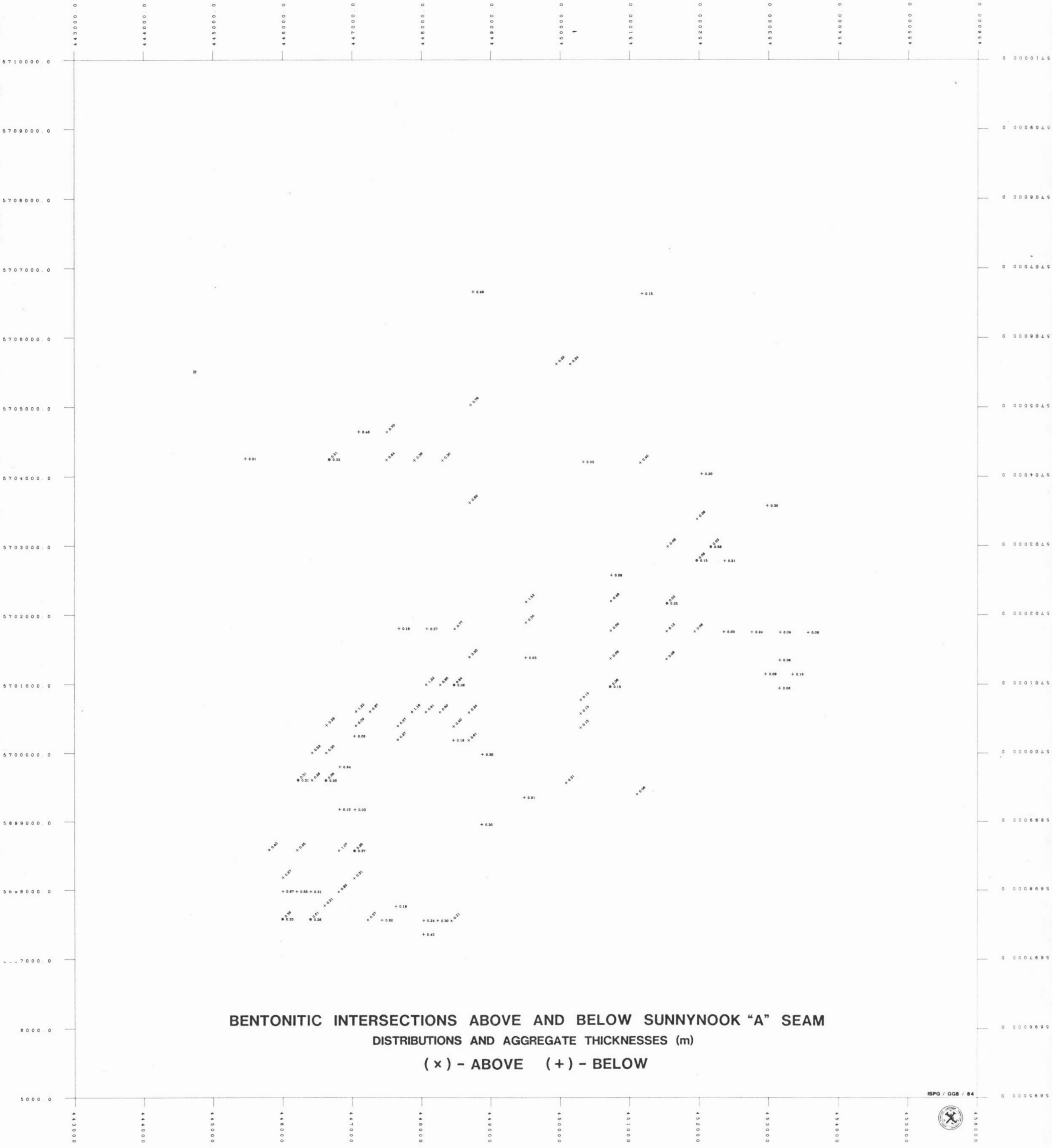
n = 288

∝= > 60%



INTERVAL BETWEEN MARKER2 AND RICHDALE ZONE

FIGURE 46



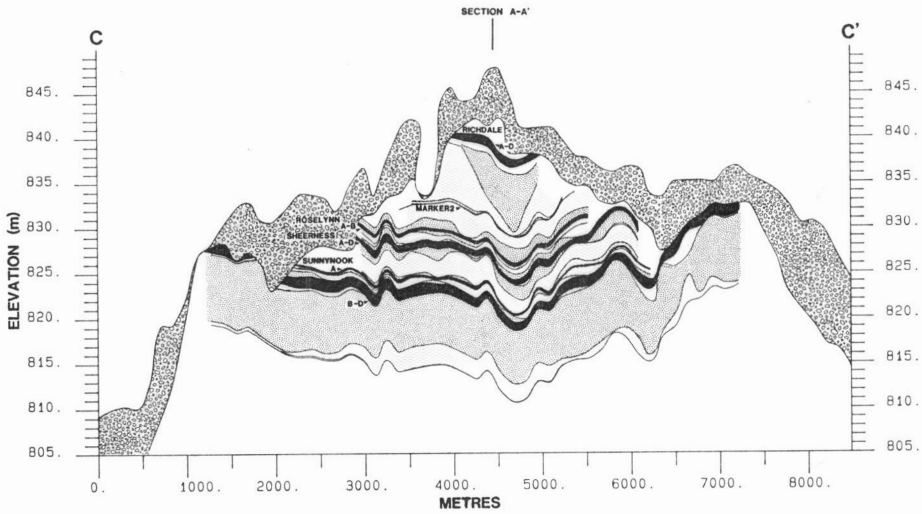
BENTONITIC INTERSECTIONS ABOVE AND BELOW SUNNYNOOK "A" SEAM

DISTRIBUTIONS AND AGGREGATE THICKNESSES (m)

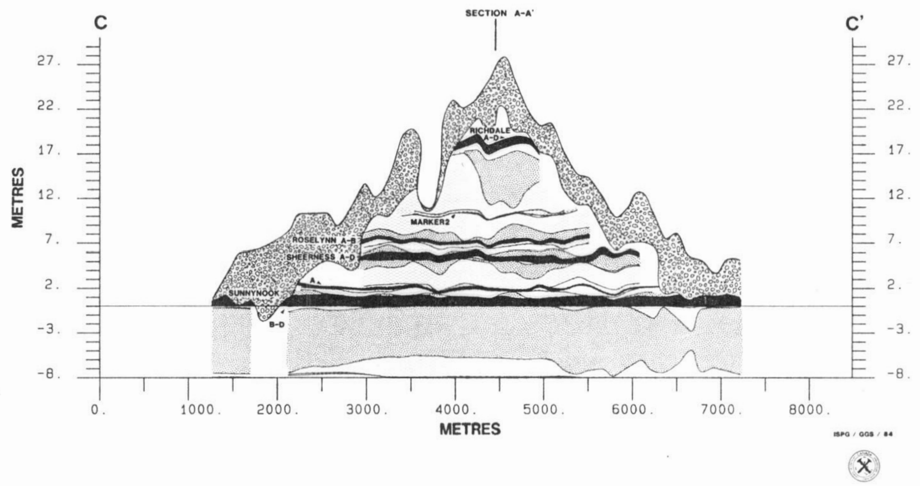
(×) - ABOVE (+) - BELOW

ISPG / GGS / 84

FIGURE 47

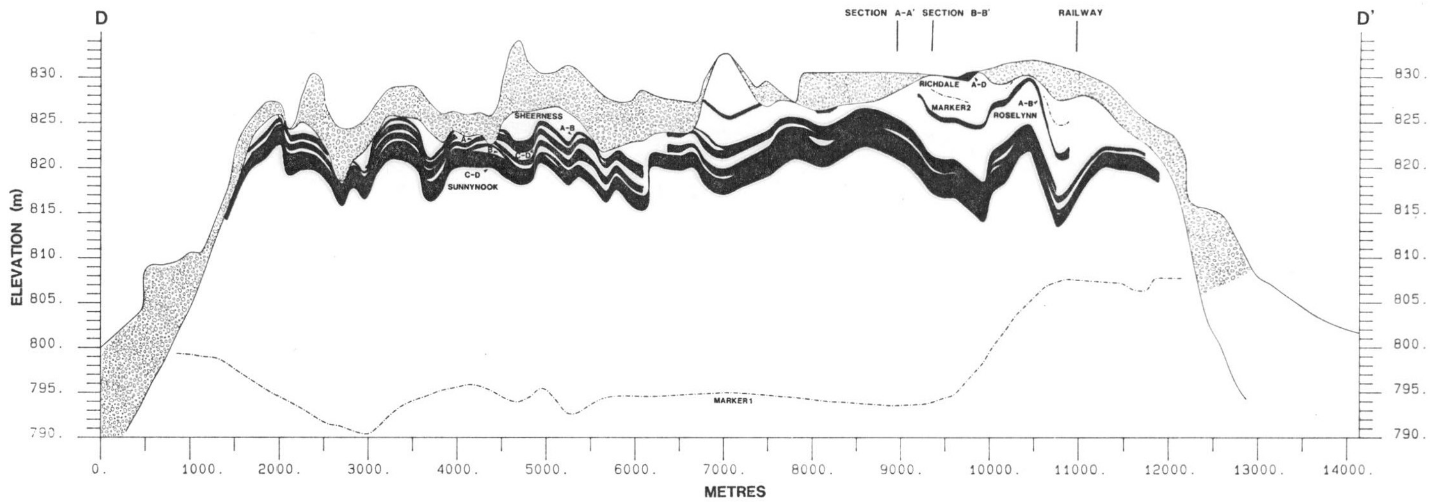


CROSS SECTION C - C' (Sea level Datum)

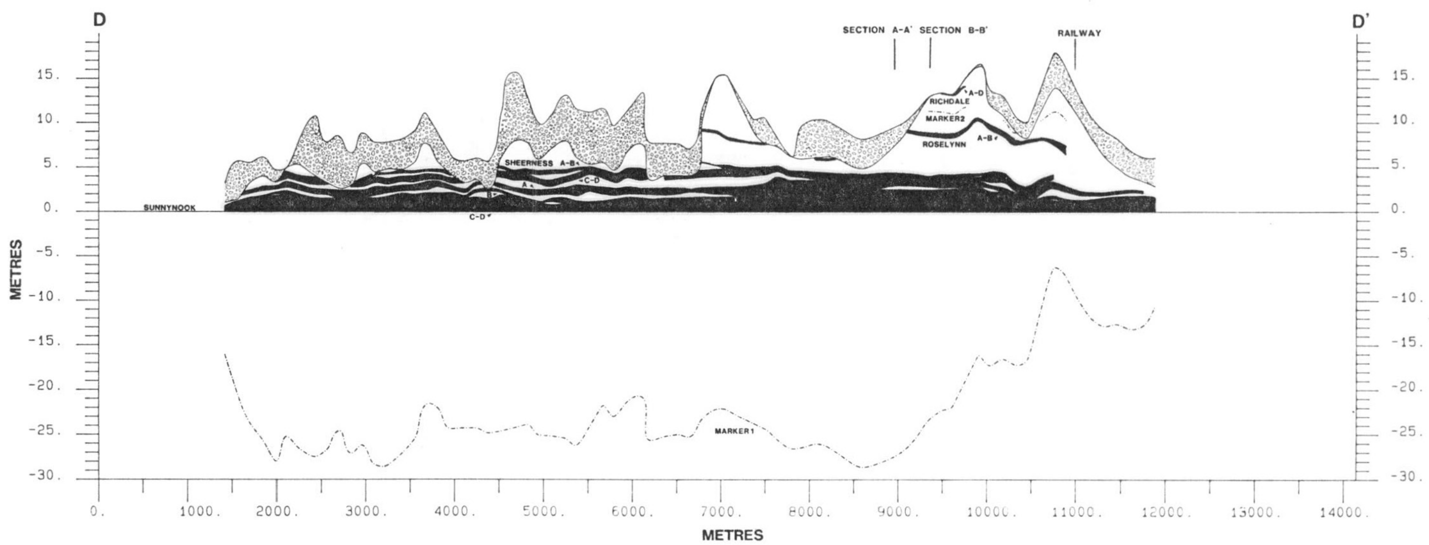


CROSS SECTION C - C' (Sunnynook Datum)

FIGURE 48



CROSS SECTION D - D' (Sea Level Datum)



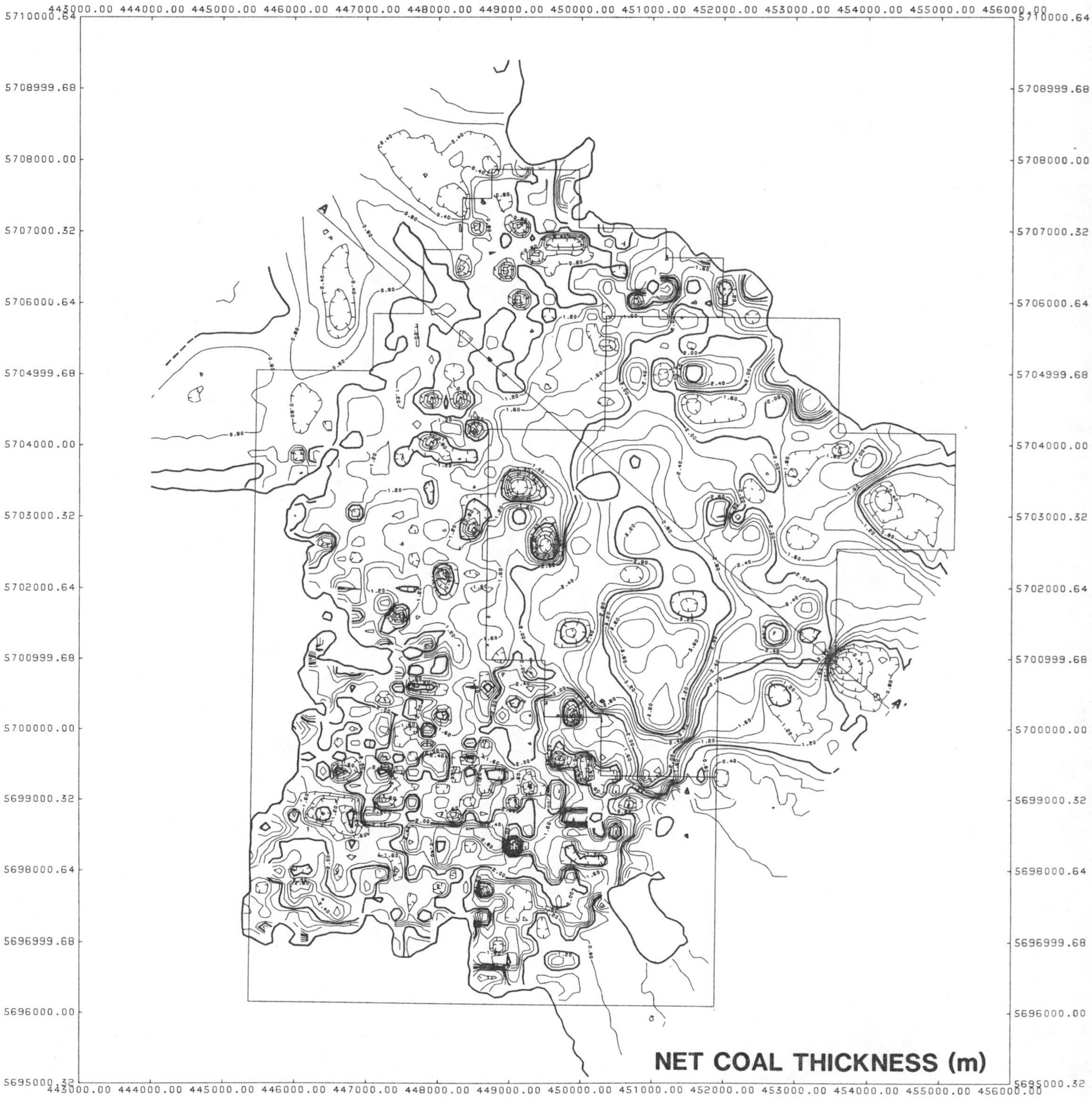
CROSS SECTION D - D' (Sunnynook Datum)

ISPG / GGS / 84

SUNNYNOOK COAL ZONE

(FIGS. 49a-d)

FIGURE 49a



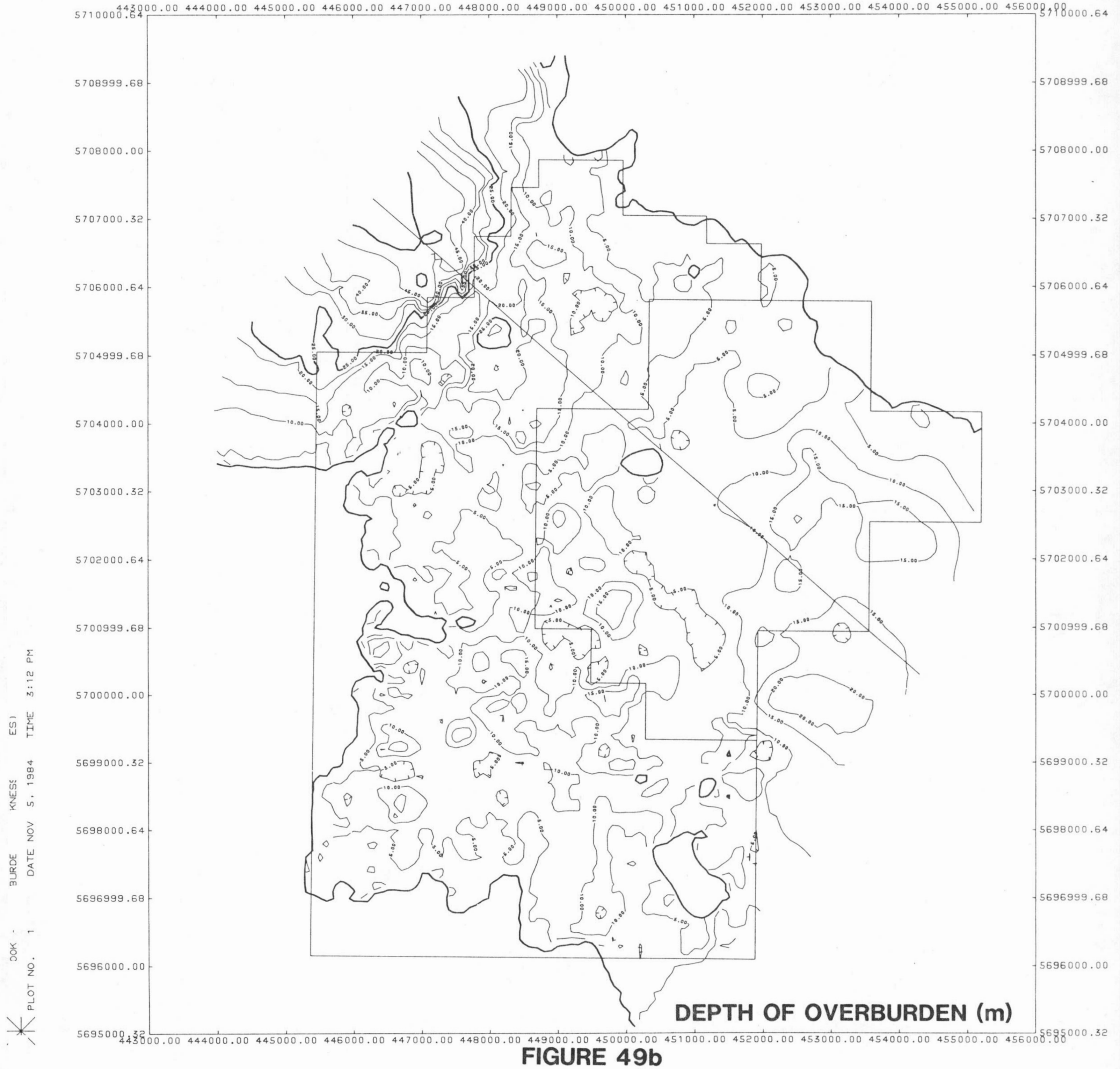

DEPTH OF OVERBURDEN (m)
443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
5710000.64
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
PLOT NO. 1 DATE NOV 5, 1984 TIME 3:12 PM

FIGURE 49b

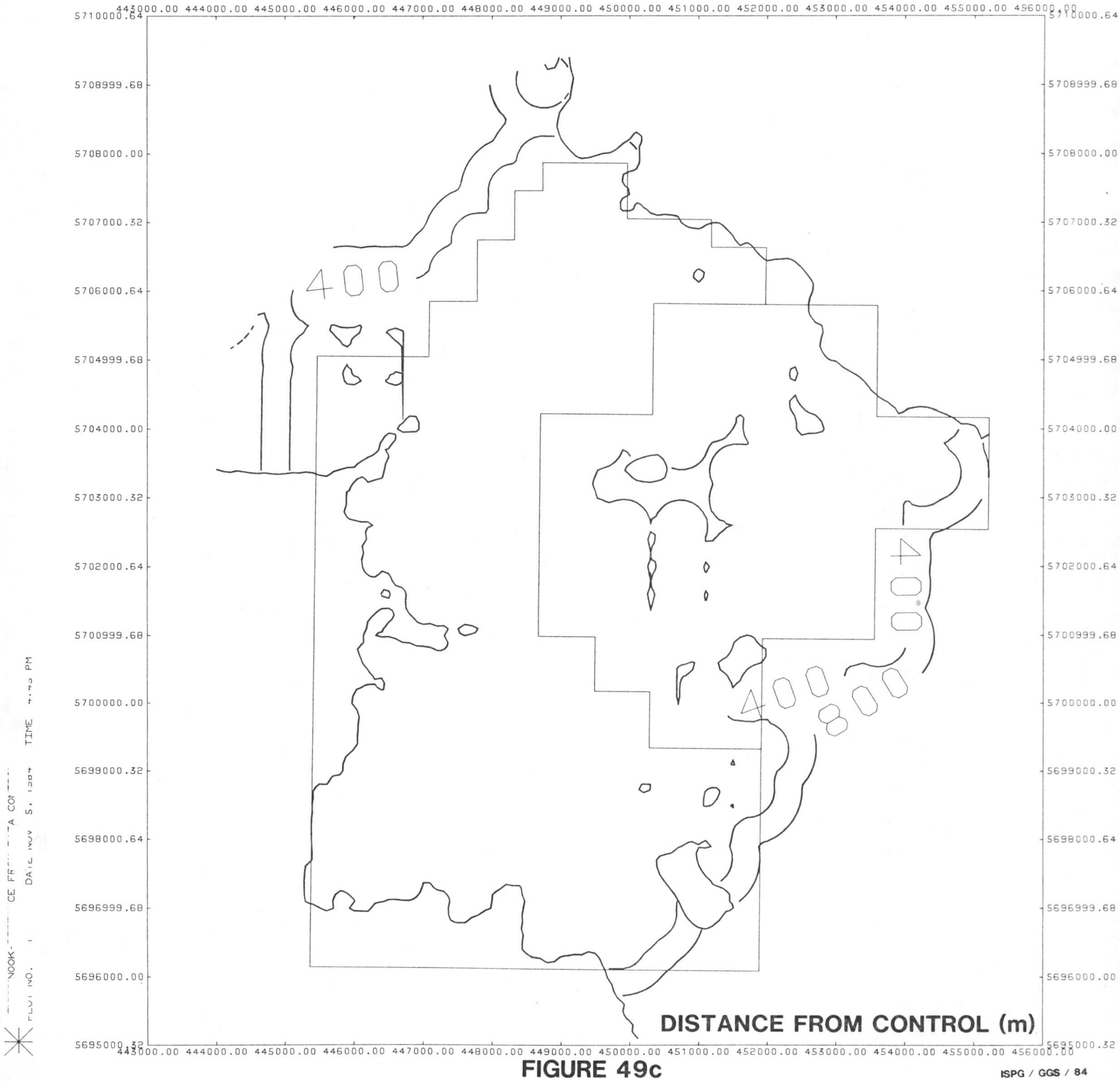
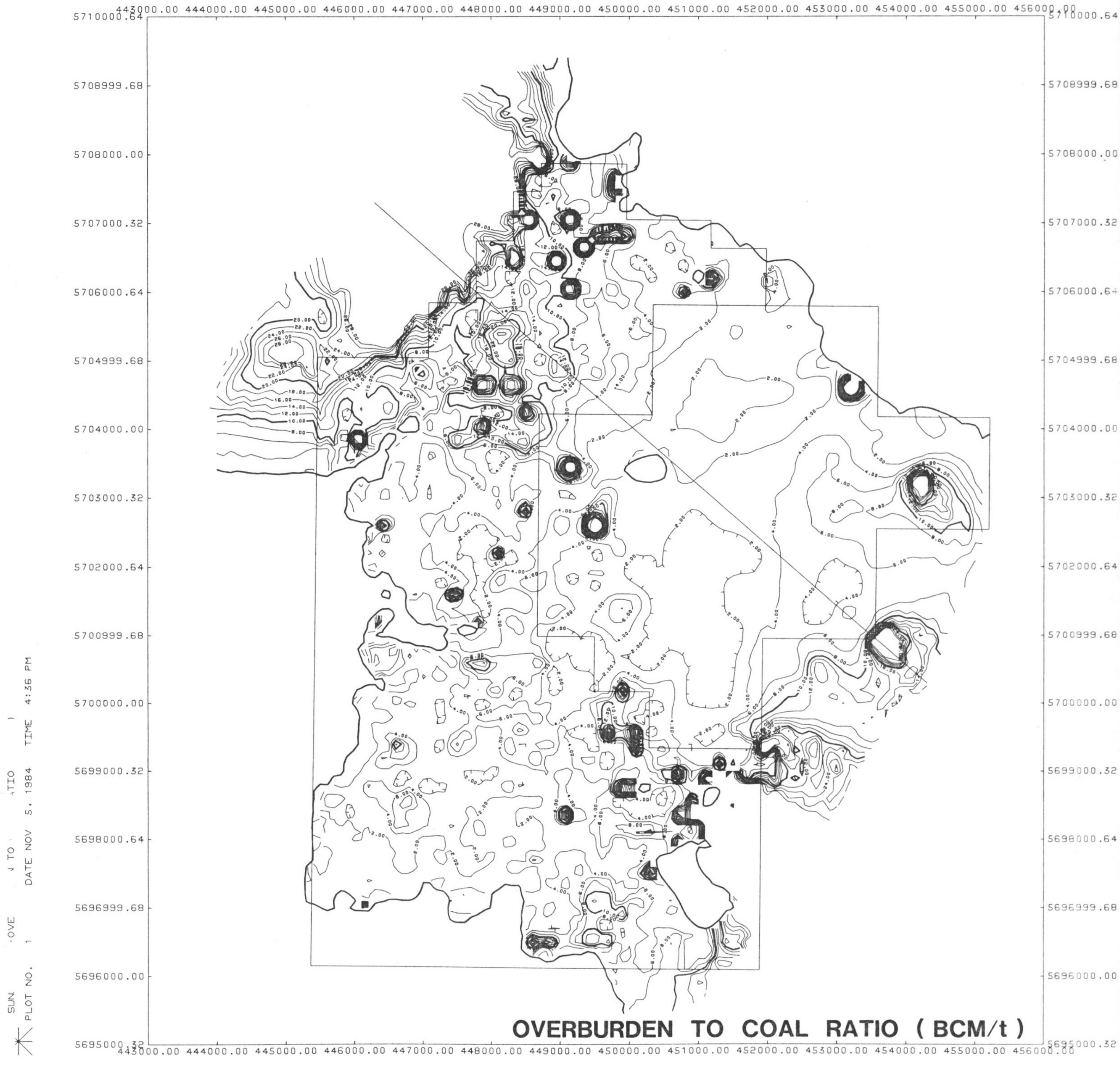


FIGURE 49c

ISPG / GGS / 84

FIGURE 49d

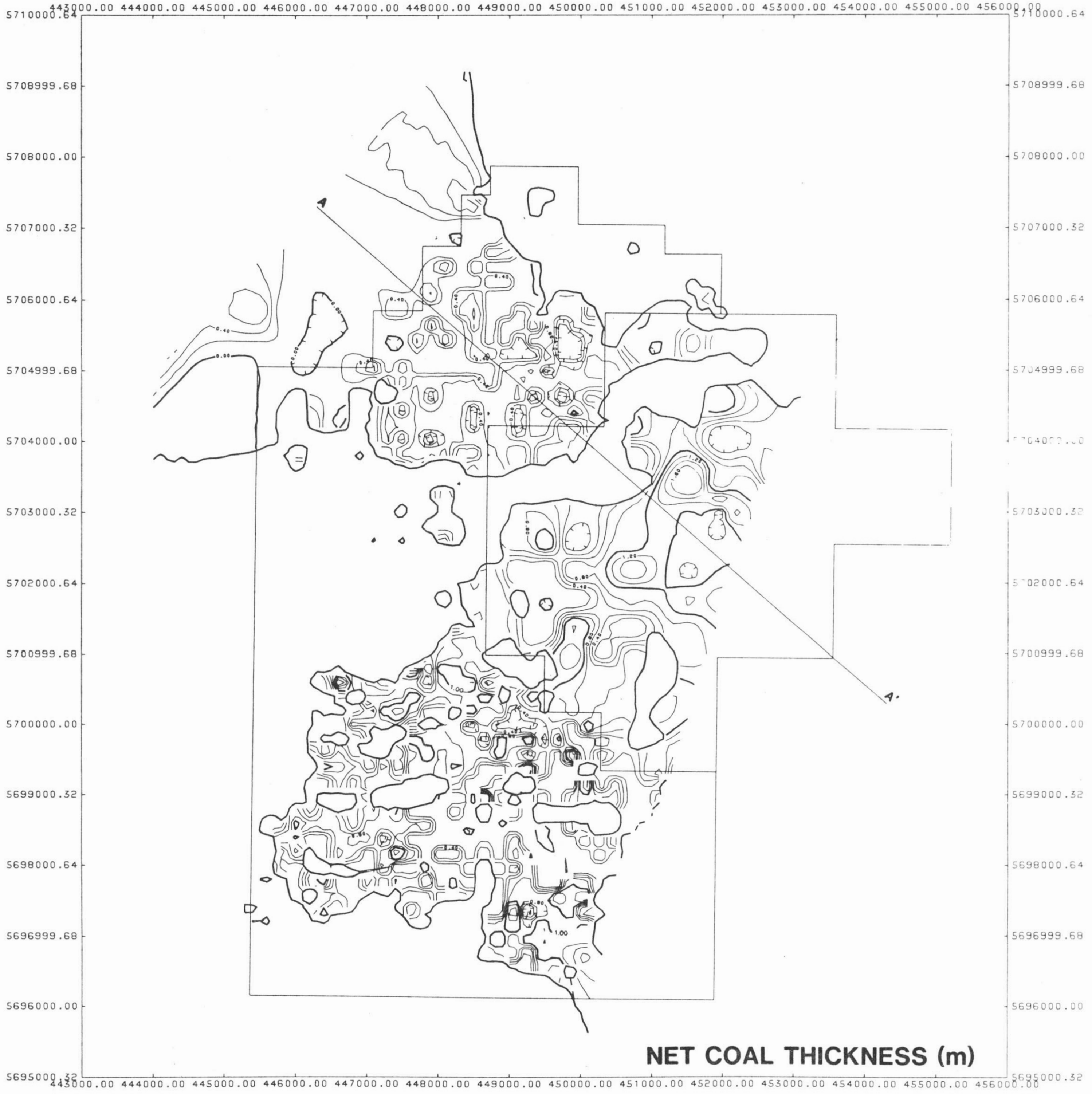


OVERBURDEN TO COAL RATIO (BCM/t)

SHEERNESS COAL ZONE

(FIGS. 50a-c)

FIGURE 50a



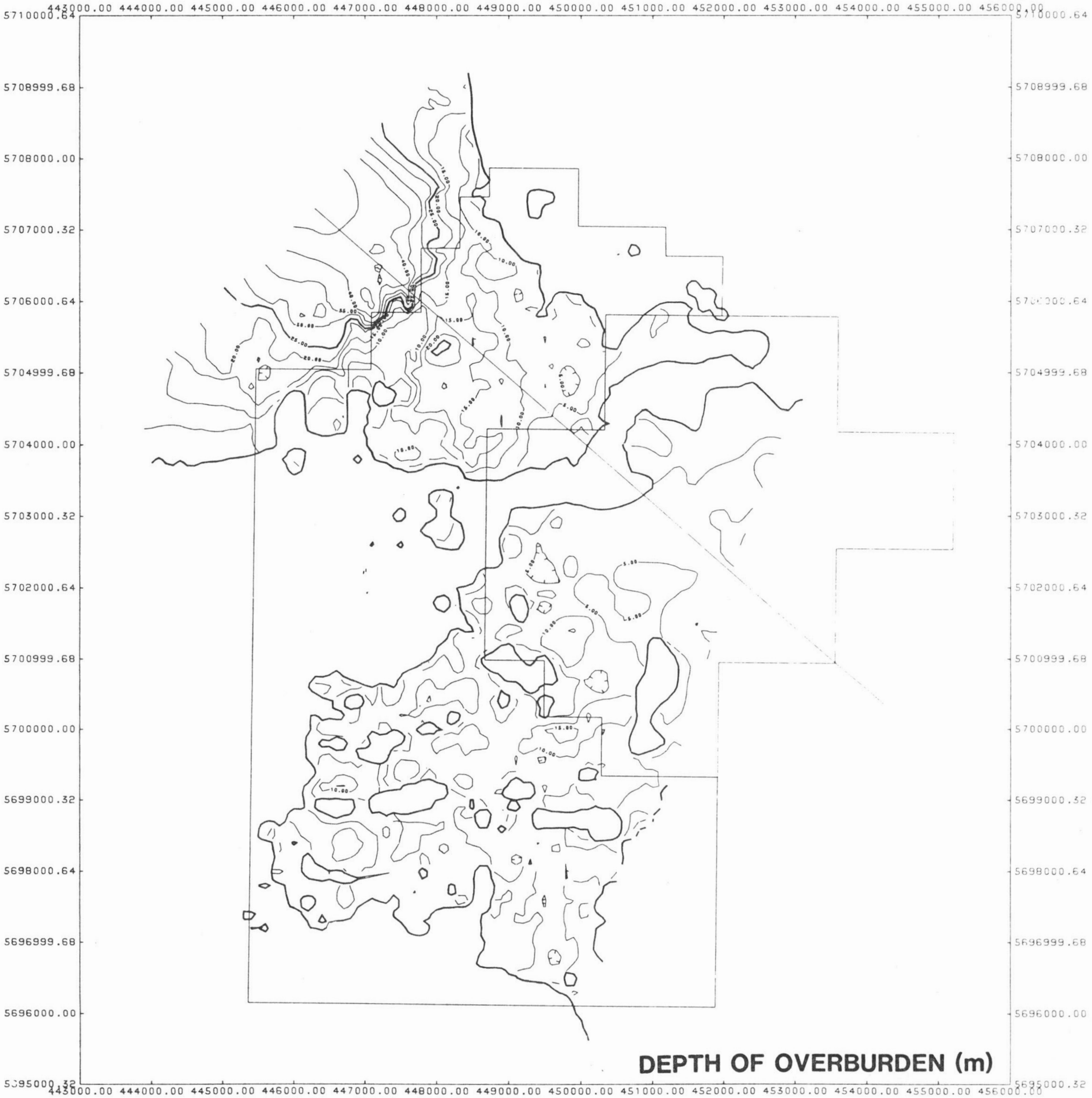


FIGURE 50b

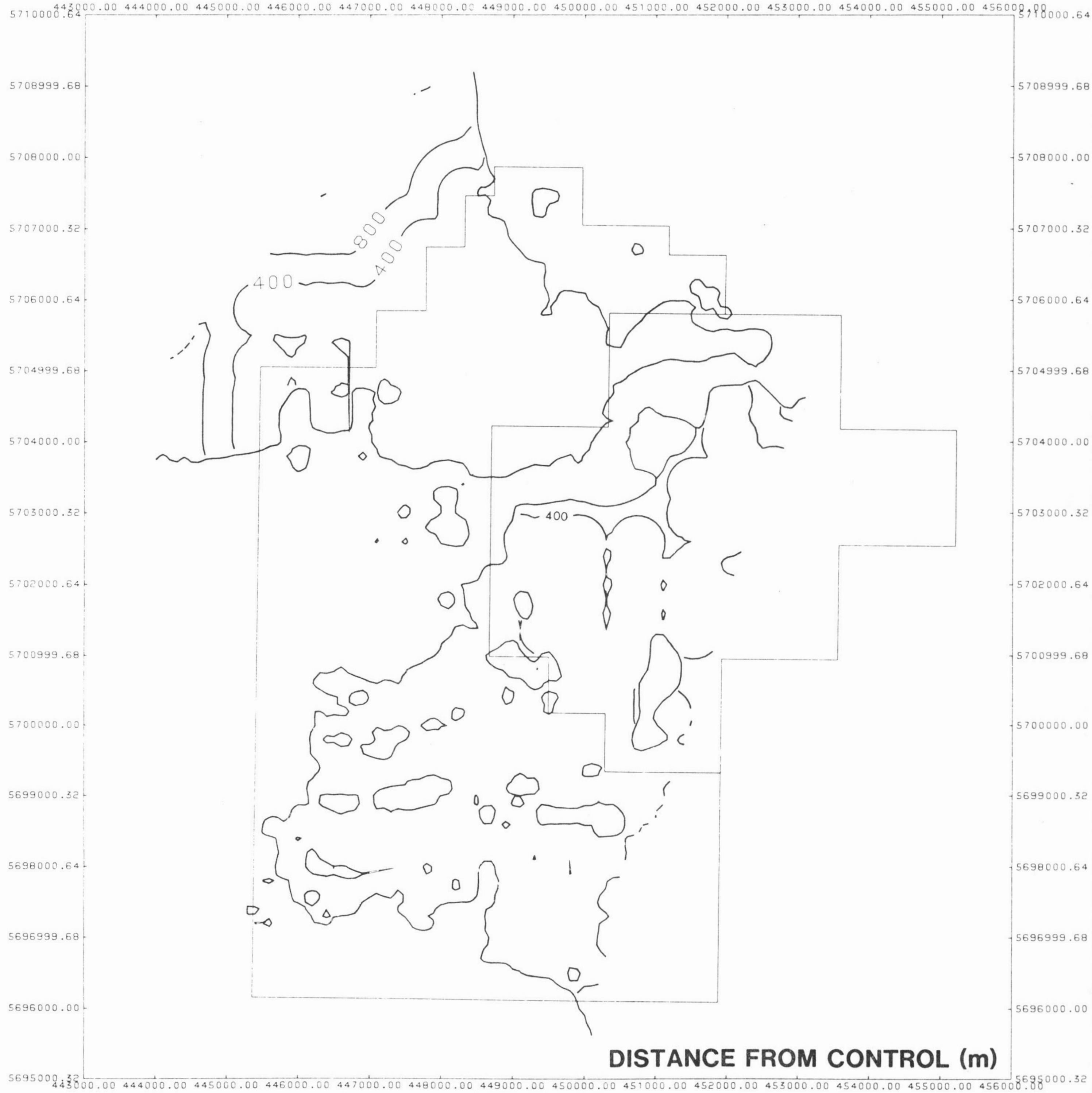


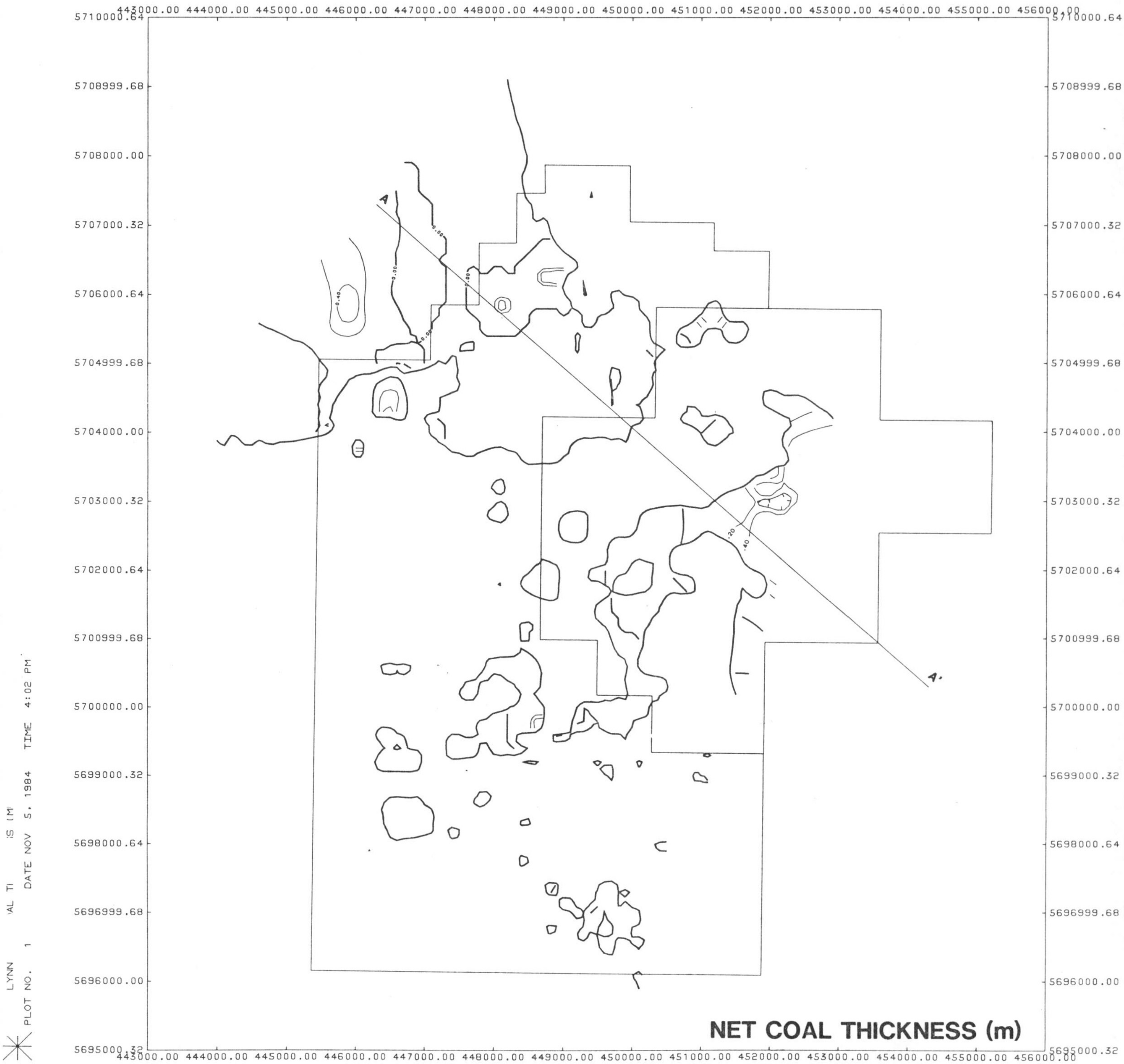
FIGURE 50c

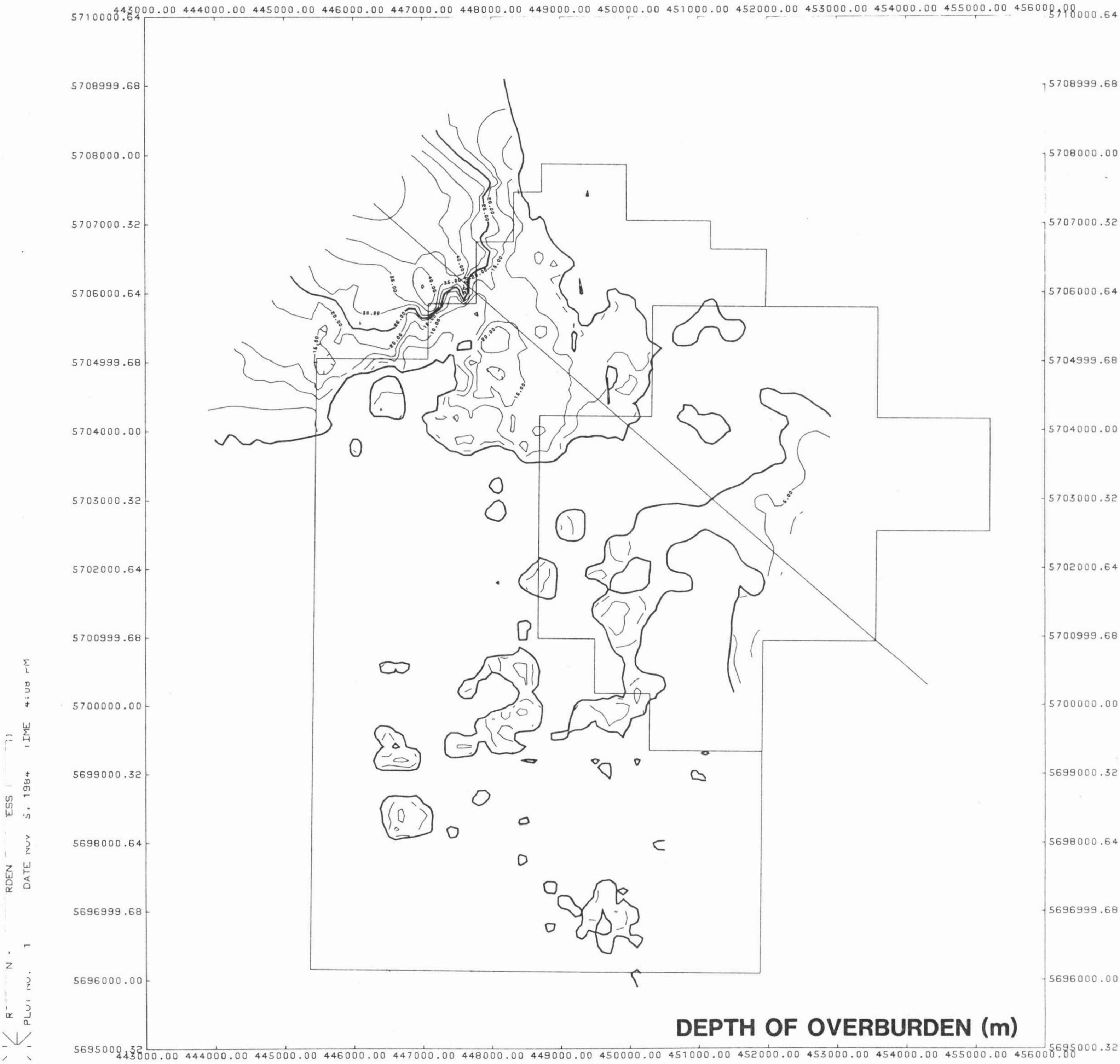
ISPG / GGS / 84

ROSELYNN COAL ZONE

(FIGS. 51a-c)

FIGURE 51a




443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
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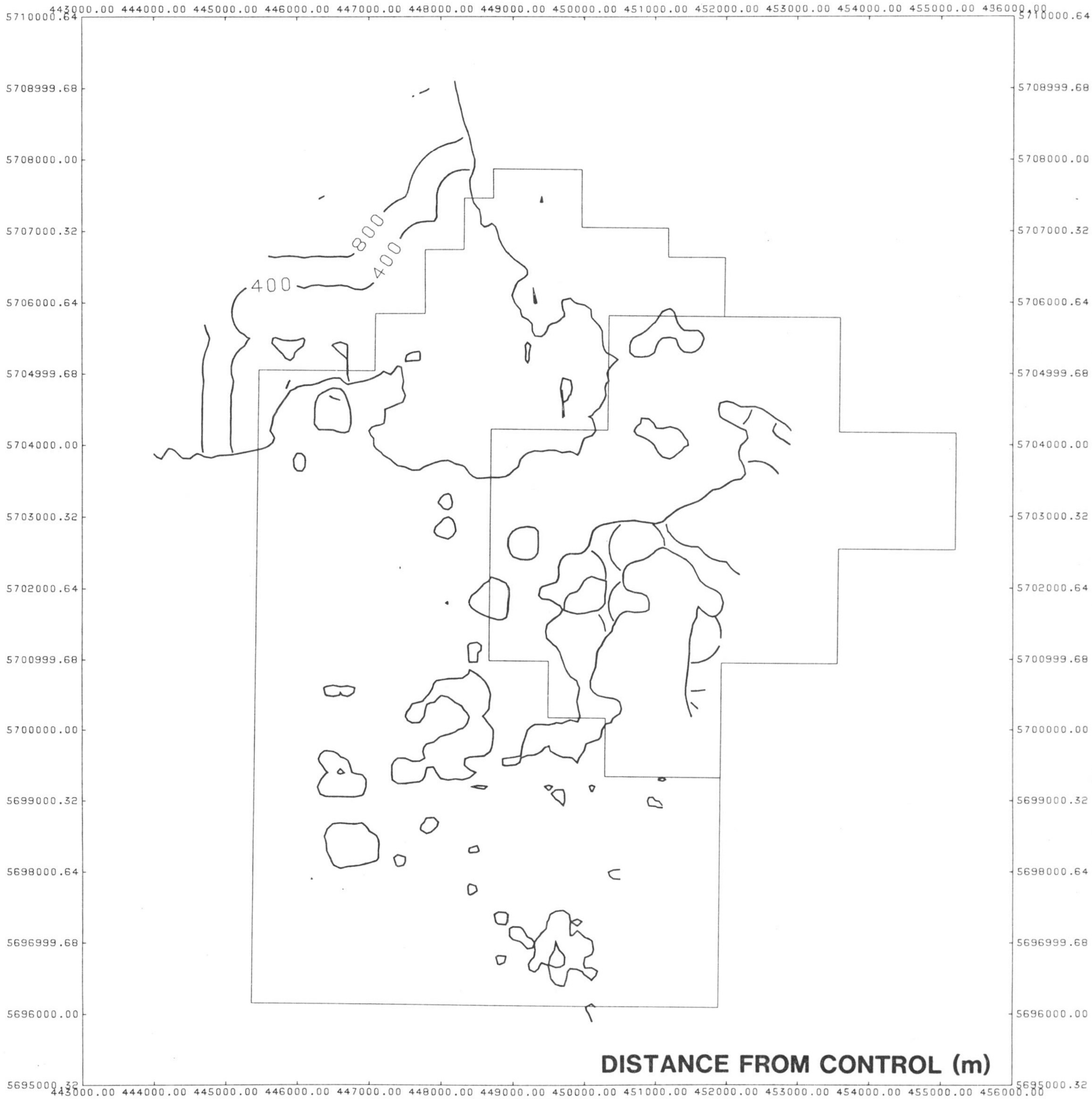
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
DEPTH OF OVERBURDEN (m)

FIGURE 51b



YNN-C E FRC CONT
PLOT NO. 1 DATE NOV 5, 1984 TIME 6:05 PM

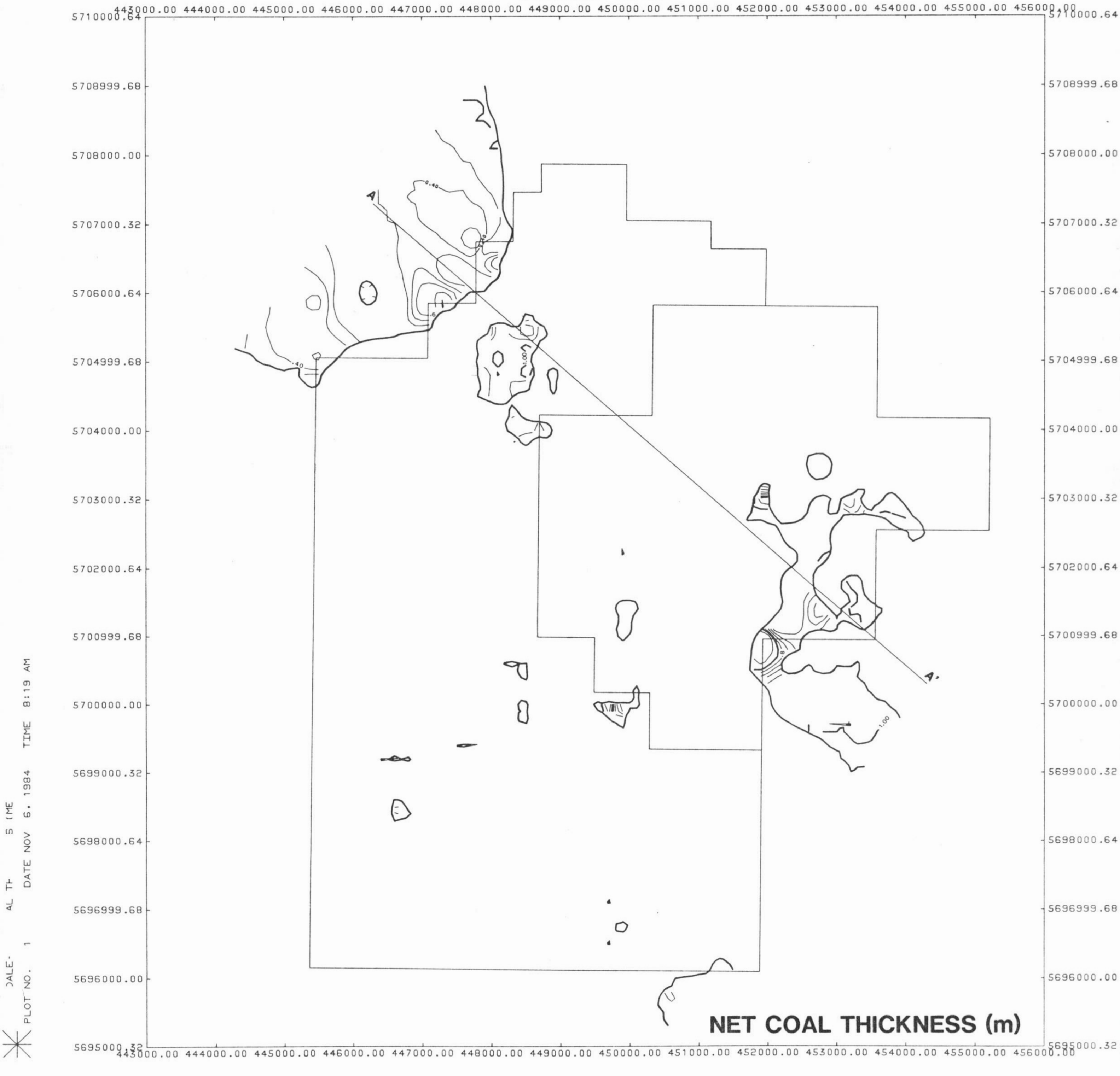
FIGURE 51c

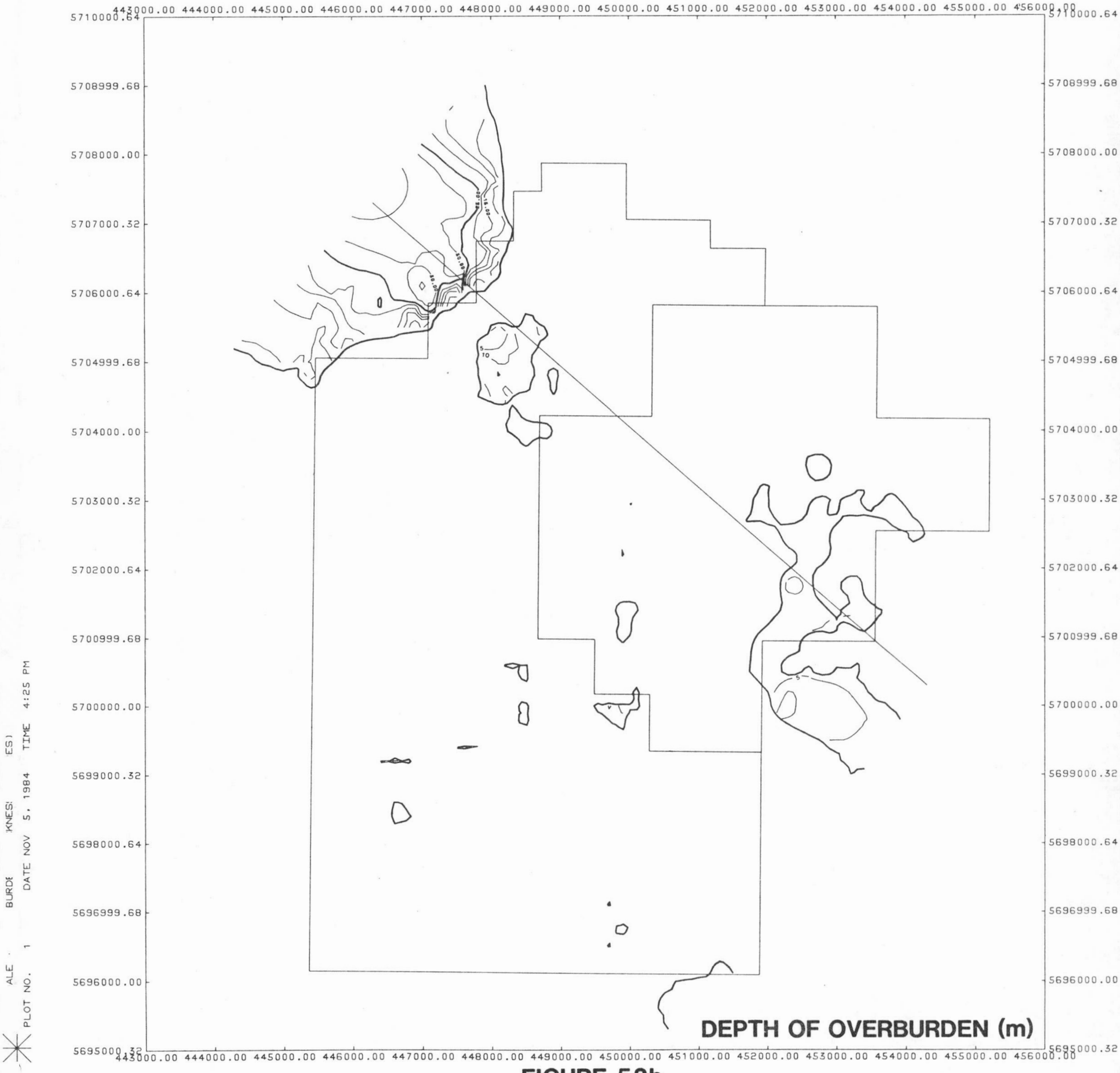
ISPG / GGS / 84

RICHDALE COAL ZONE

(FIGS. 52a-c)

FIGURE 52a

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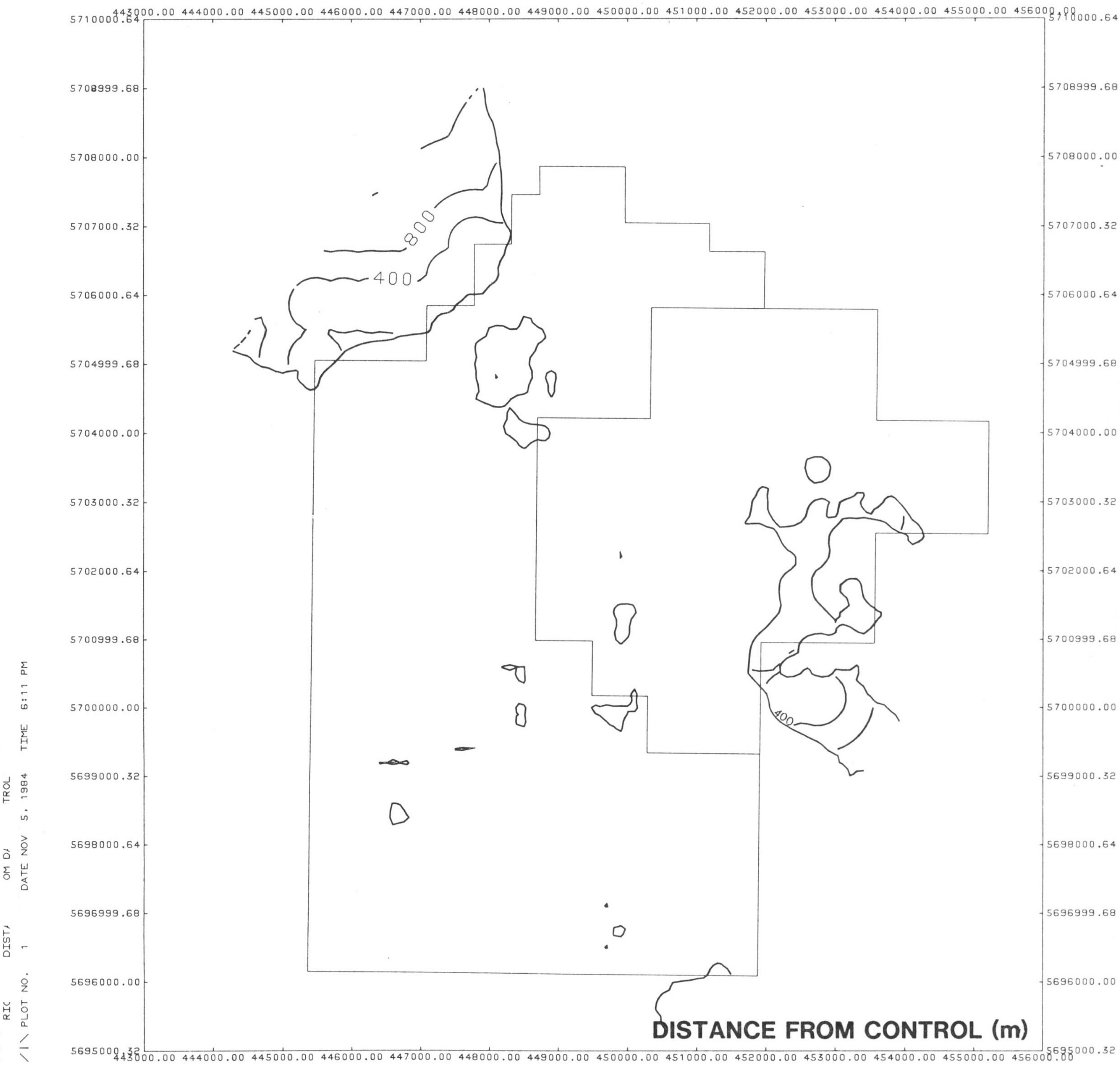
5710000.64
5708999.68
5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
DEPTH OF OVERBURDEN (m)
PLOT NO. 1 DATE NOV 5, 1984 TIME 4:25 PM

FIGURE 52b


443000.00 444000.00 445000.00 446000.00 447000.00 448000.00 449000.00 450000.00 451000.00 452000.00 453000.00 454000.00 455000.00 456000.00
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5708000.00
5707000.32
5706000.64
5704999.68
5704000.00
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
800
400
400
DISTANCE FROM CONTROL (m)
PLOT NO. 1
DATE NOV 5, 1984
TIME 6:11 PM

FIGURE 52c

AGGREGATE NET COAL THICKNESS

(FIGS. 53a-b)

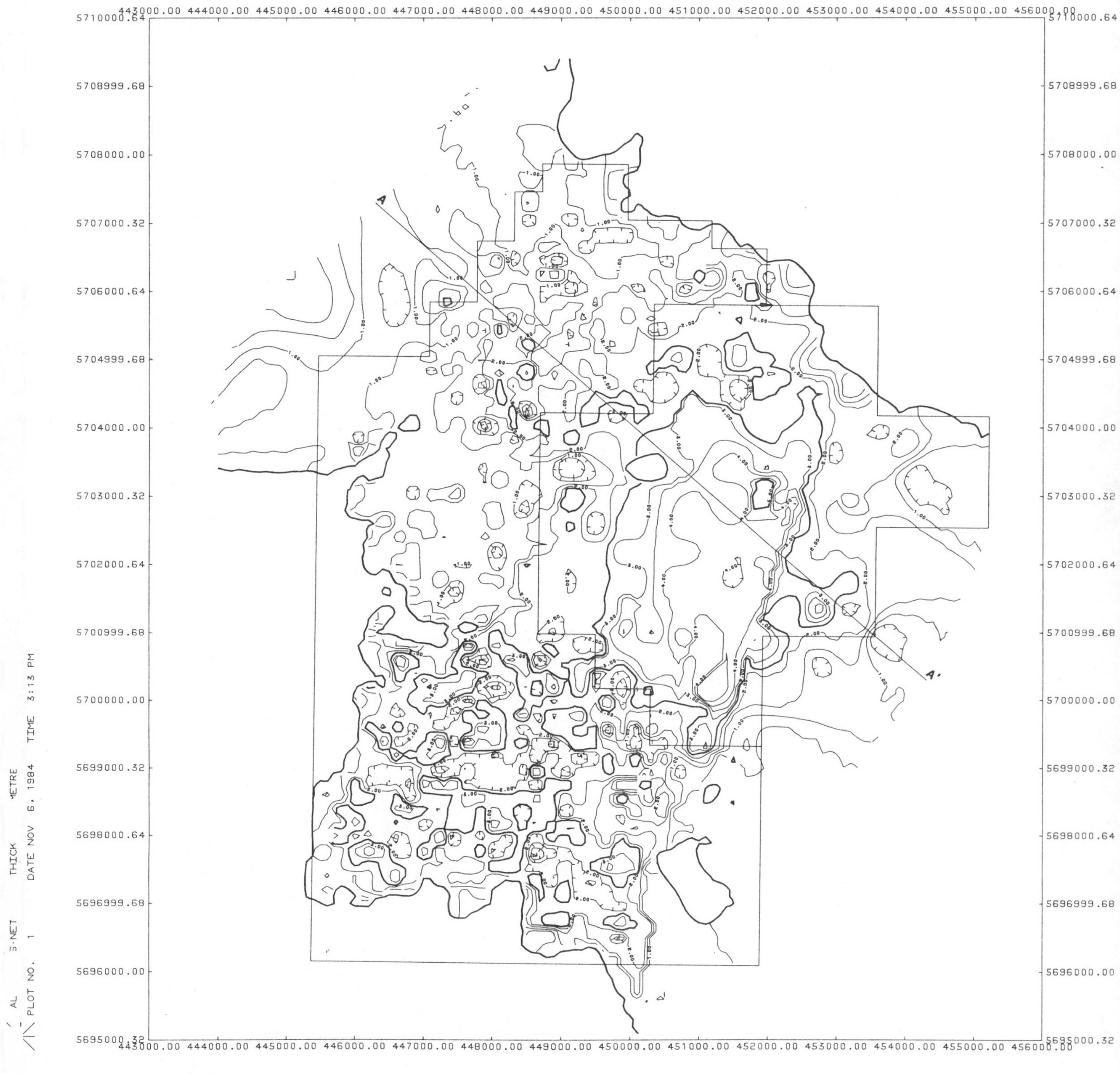
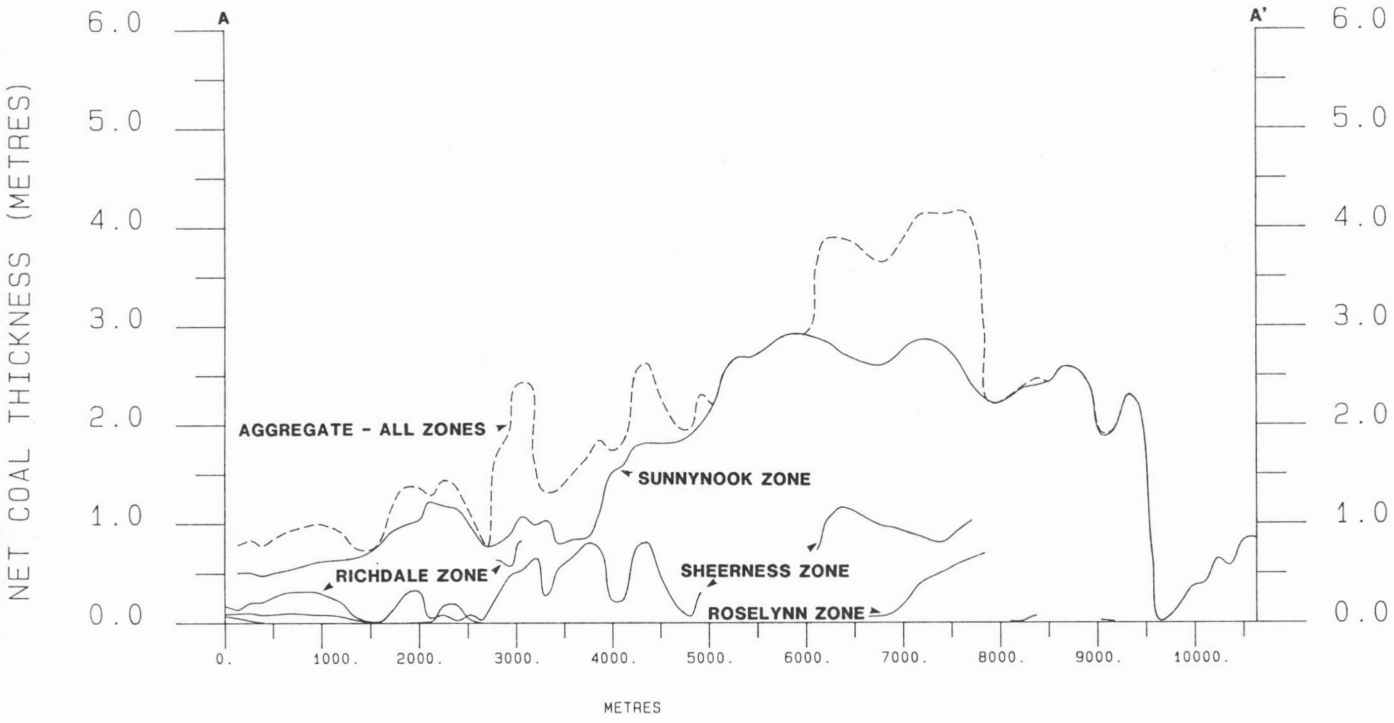
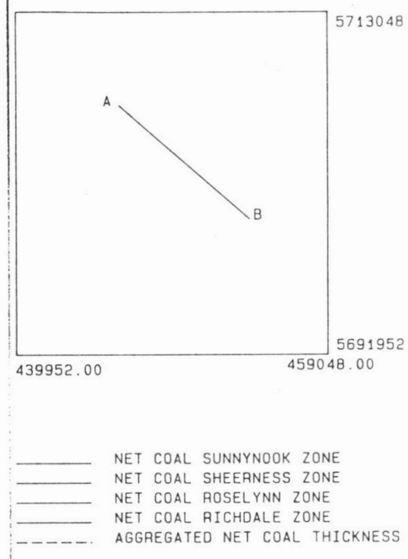


FIGURE 53a





SECTION A-A' NET COAL THICKNESSES

*TUE, NOV 6, 1984, 2:09 PM

ISPG / GGS / 84

FIGURE 53b

AGGREGATE OVERBURDEN DEPTH

(FIGS. 54a-b)

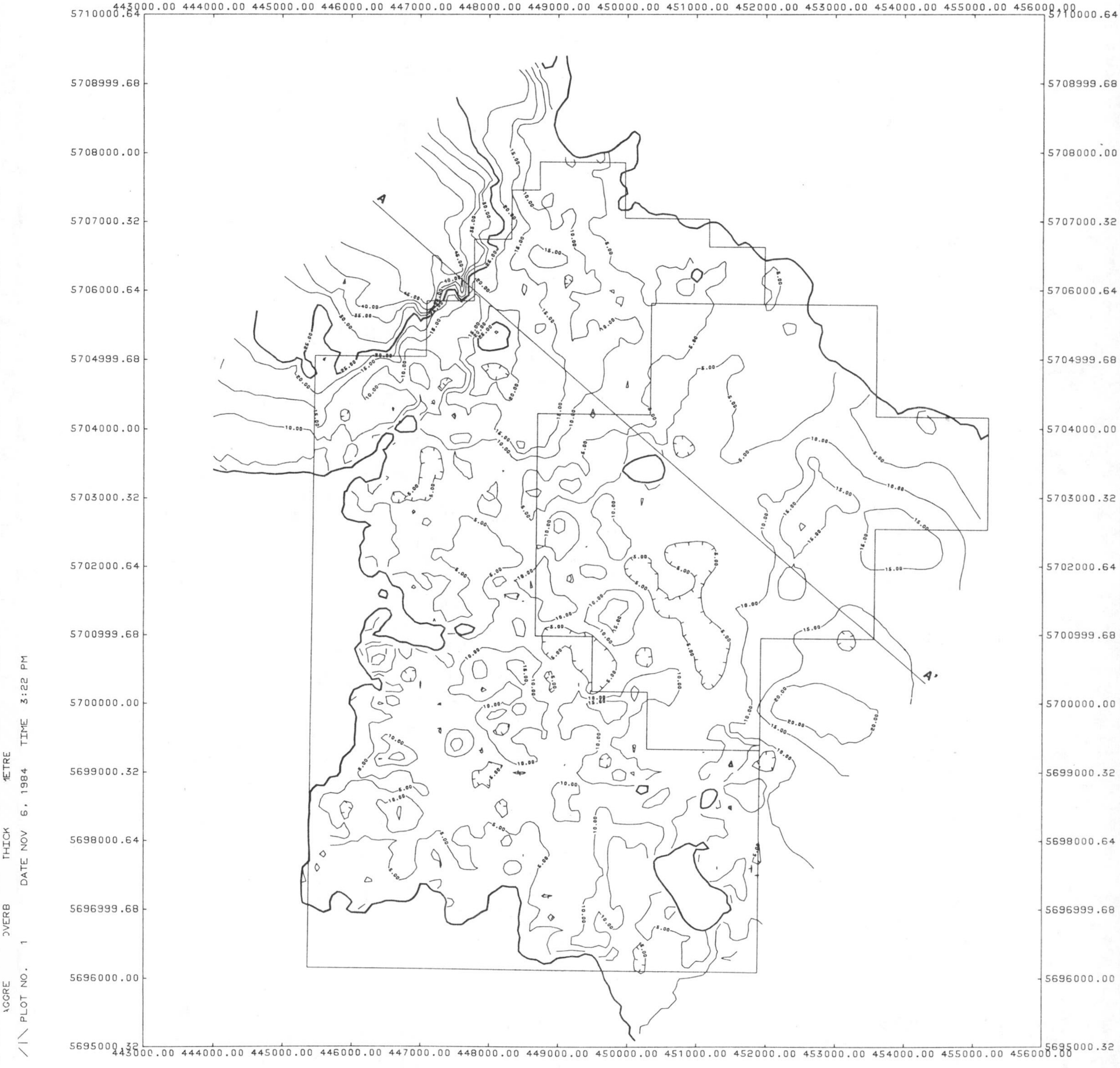
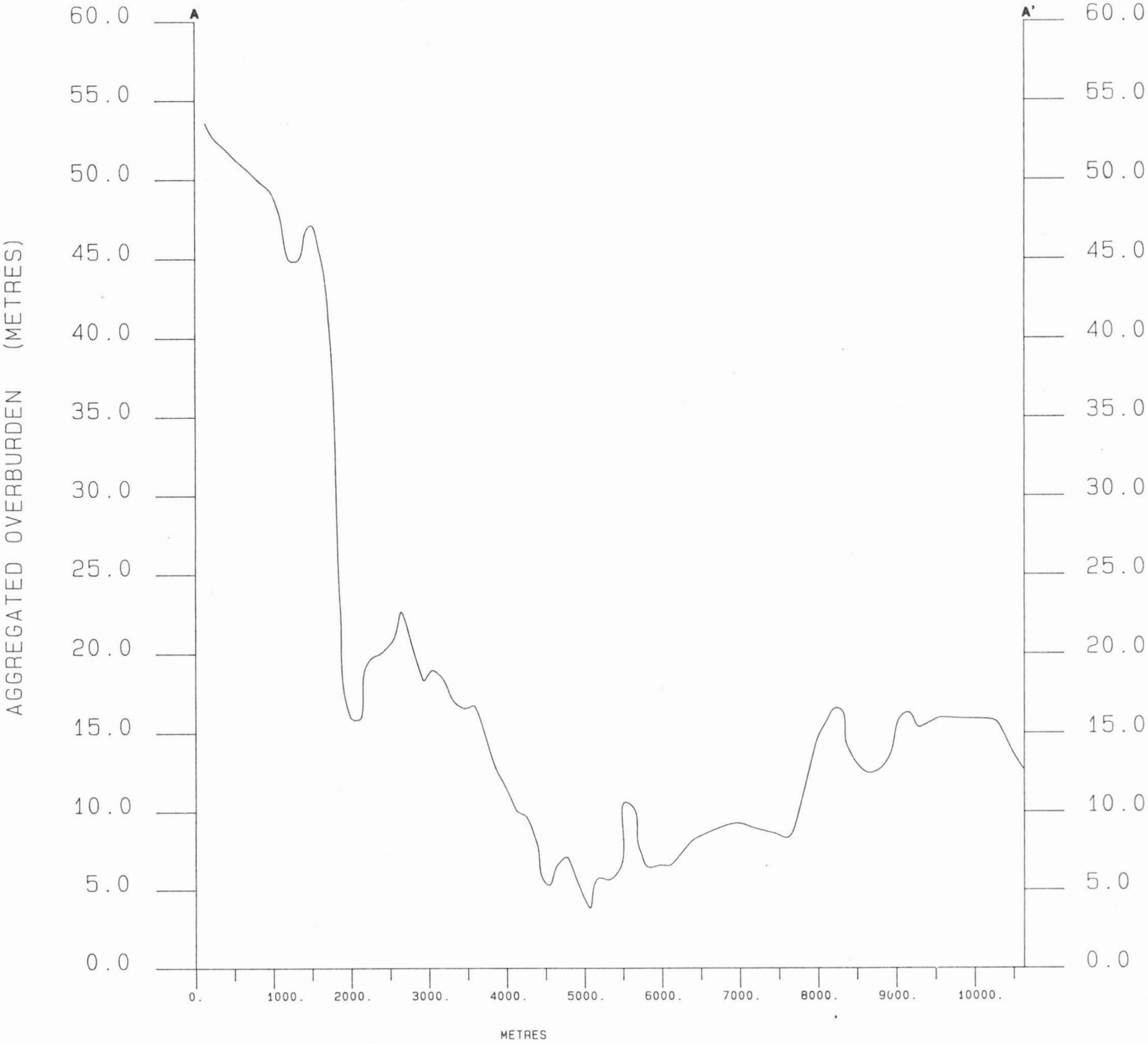


FIGURE 54a



SECTION A-A' AGGREGATED OVERBURDEN DEPTH (METRES)

*TUE, NOV 6, 1984, 2:15 PM

ISPG / GGS / 84

FIGURE 54b

FIGURE 63

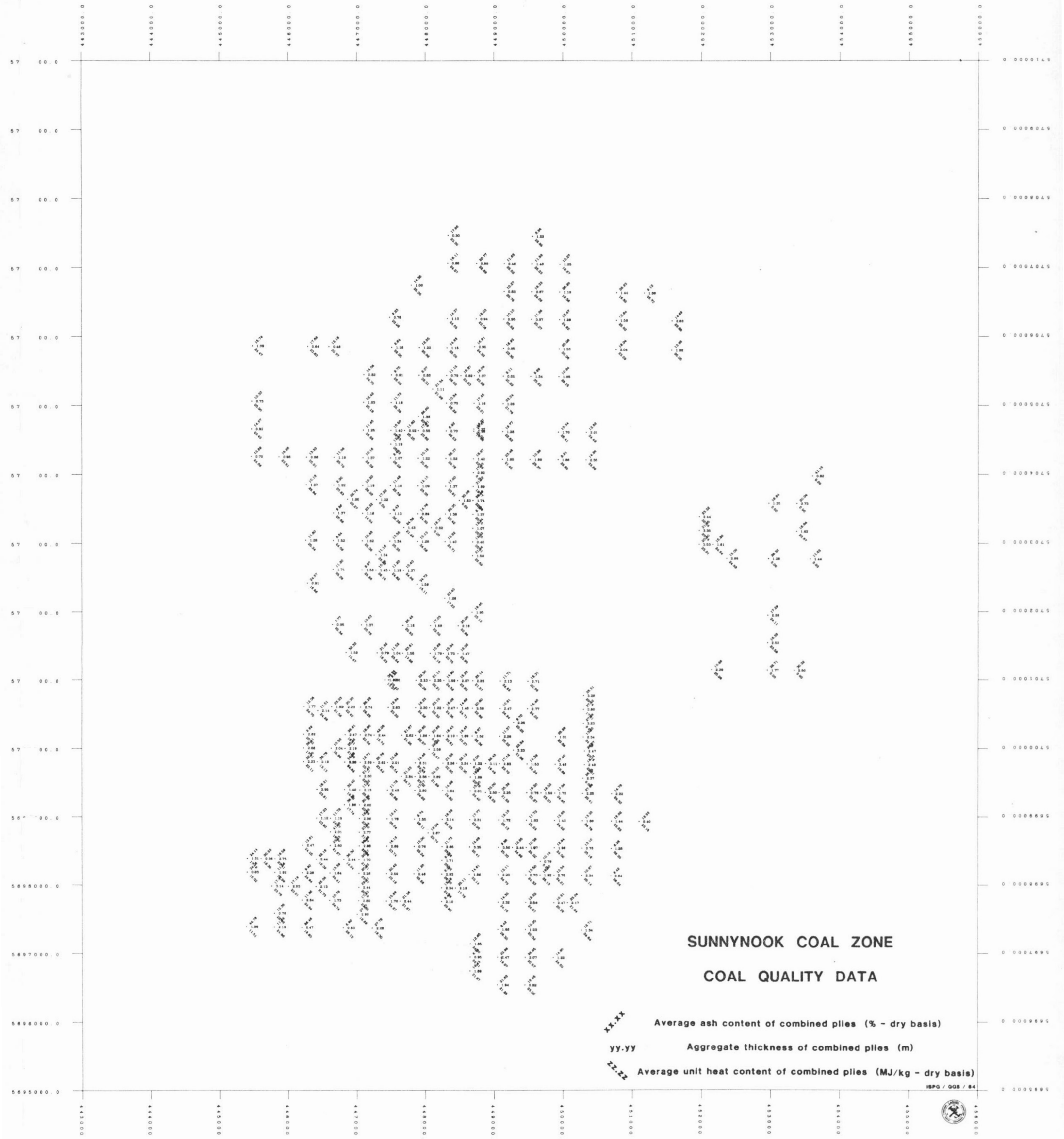
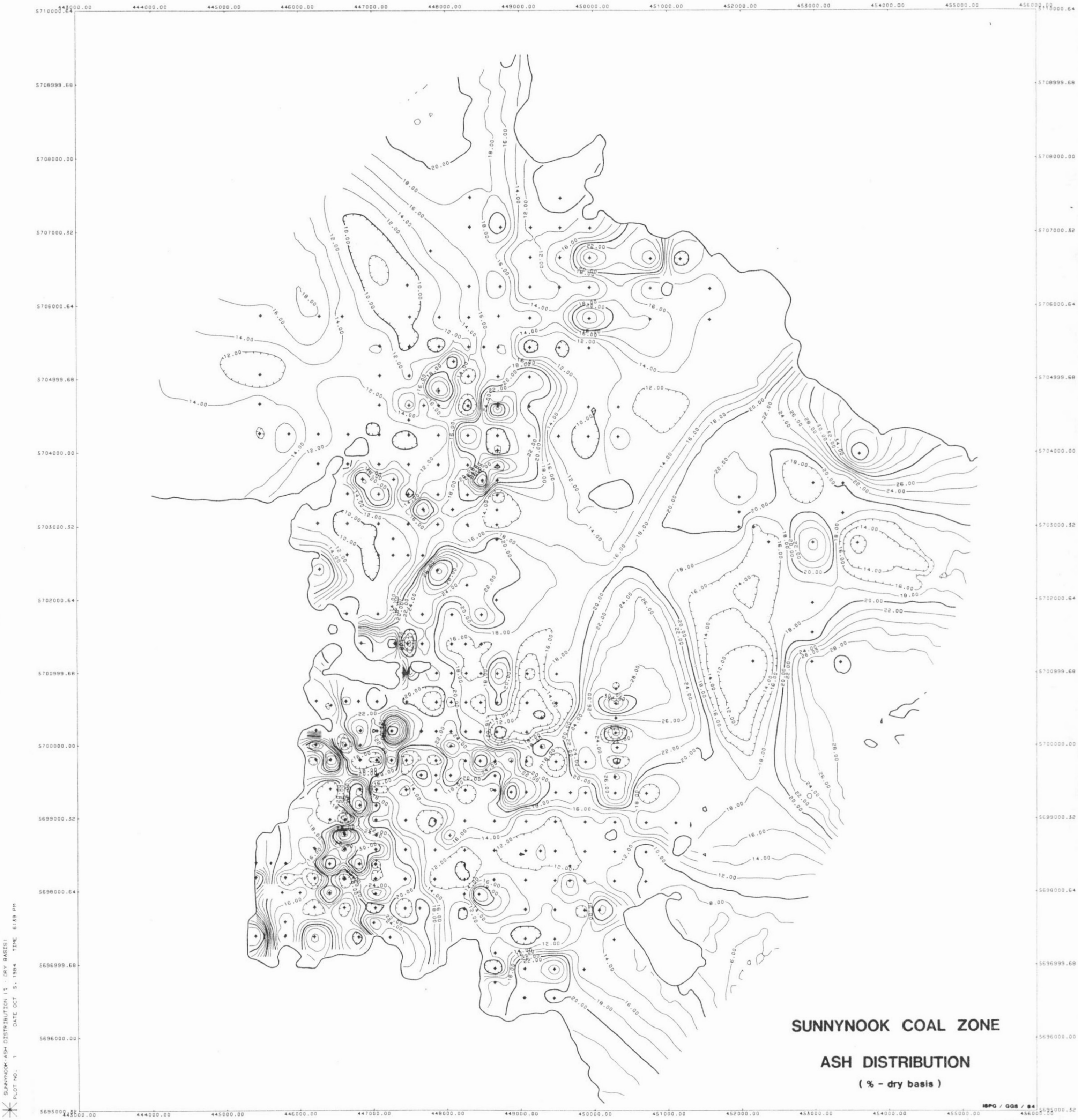

SUNNYNOOK COAL ZONE
COAL QUALITY DATA
xx.xx Average ash content of combined plies (% - dry basis)
yy.yy Aggregate thickness of combined plies (m)
zz.zz Average unit heat content of combined plies (MJ/kg - dry basis)
ISPG / GQS / 84

FIGURE 64



SUNNYNOOK COAL ZONE

ASH DISTRIBUTION

(% - dry basis)

FIGURE 65

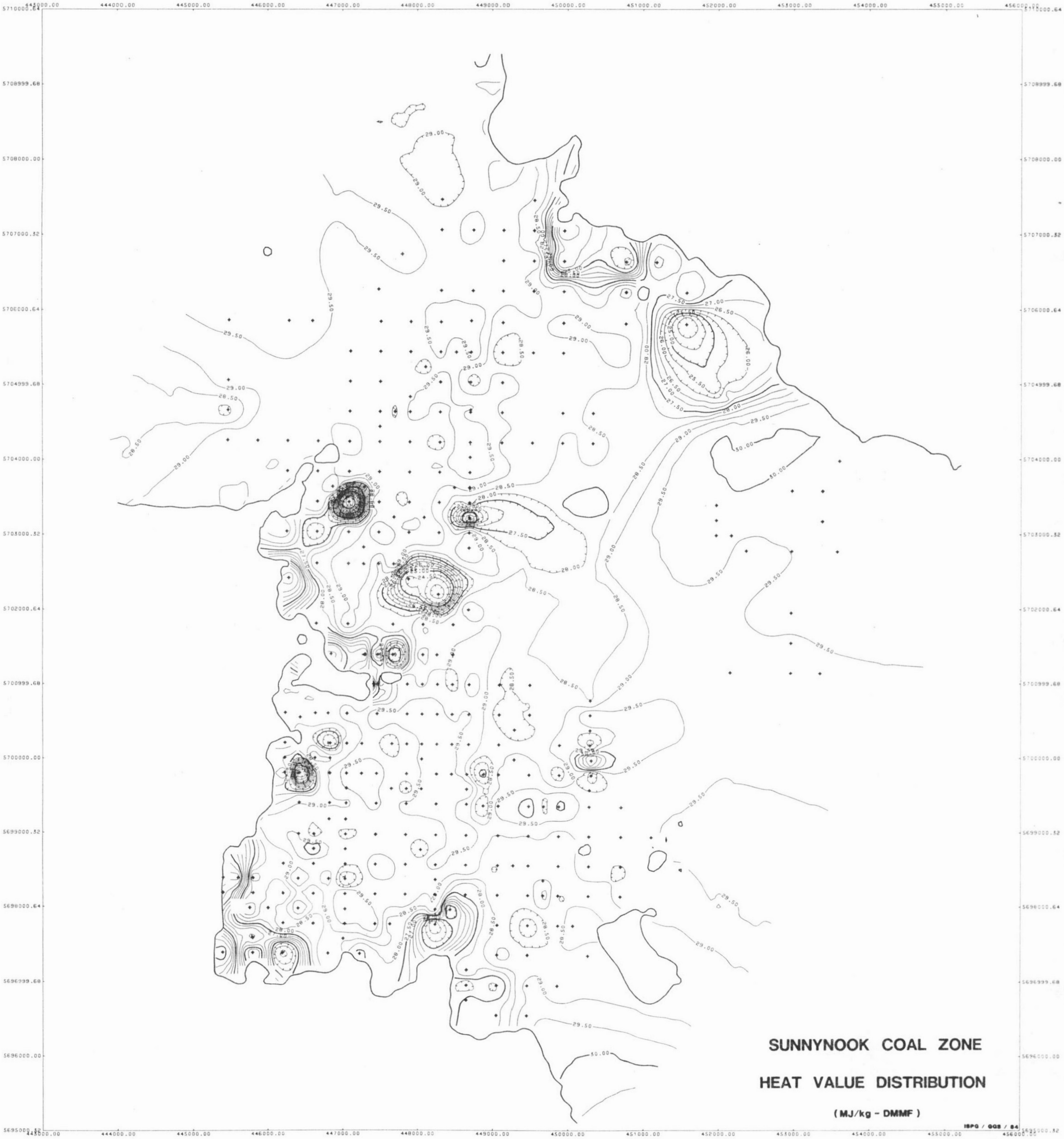

SUNNYNOOK COAL ZONE
HEAT VALUE DISTRIBUTION
(MJ/kg - DMMF)
ISPG / GGS / 84

FIGURE 66

443000.00
444000.00
445000.00
446000.00
447000.00
448000.00
449000.00
450000.00
451000.00
452000.00
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454000.00
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456000.00
5710000.64
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5707000.32
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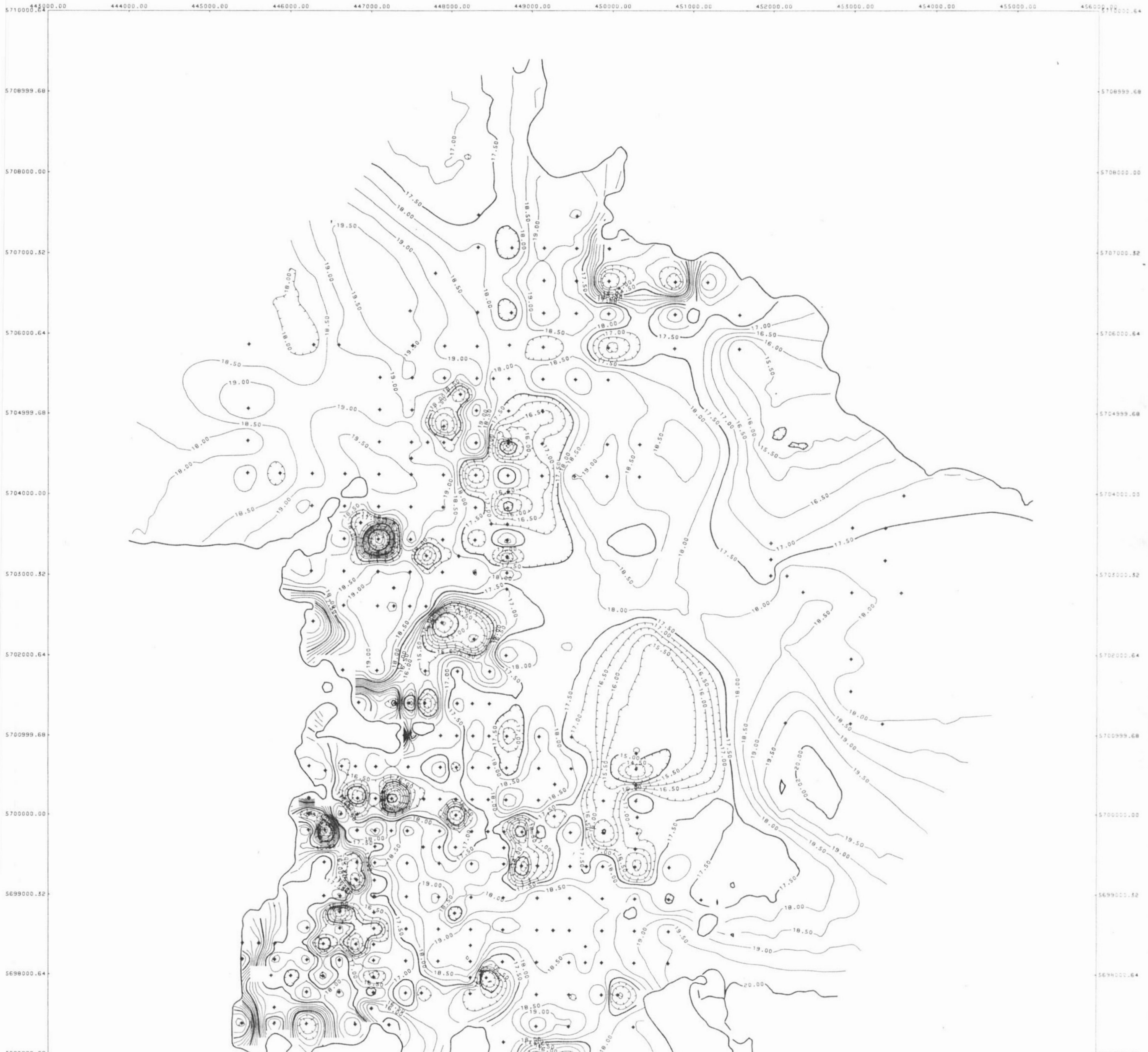
5703000.32
5702000.64
5700999.68
5700000.00
5699000.32
5698000.64
5696999.68
5696000.00
5695000.32
SUNNYNOOK COAL ZONE
ASH DISTRIBUTION
(% - 25% moisture basis)
ISPG / GGS / 84
PLOT NO. 1
DATE OCT 5, 1984 TIME 6:28 PM

FIGURE 67



SUNNYNOOK COAL ZONE

HEAT VALUE DISTRIBUTION

(MJ/kg - 25% moisture basis)

FIGURE 68

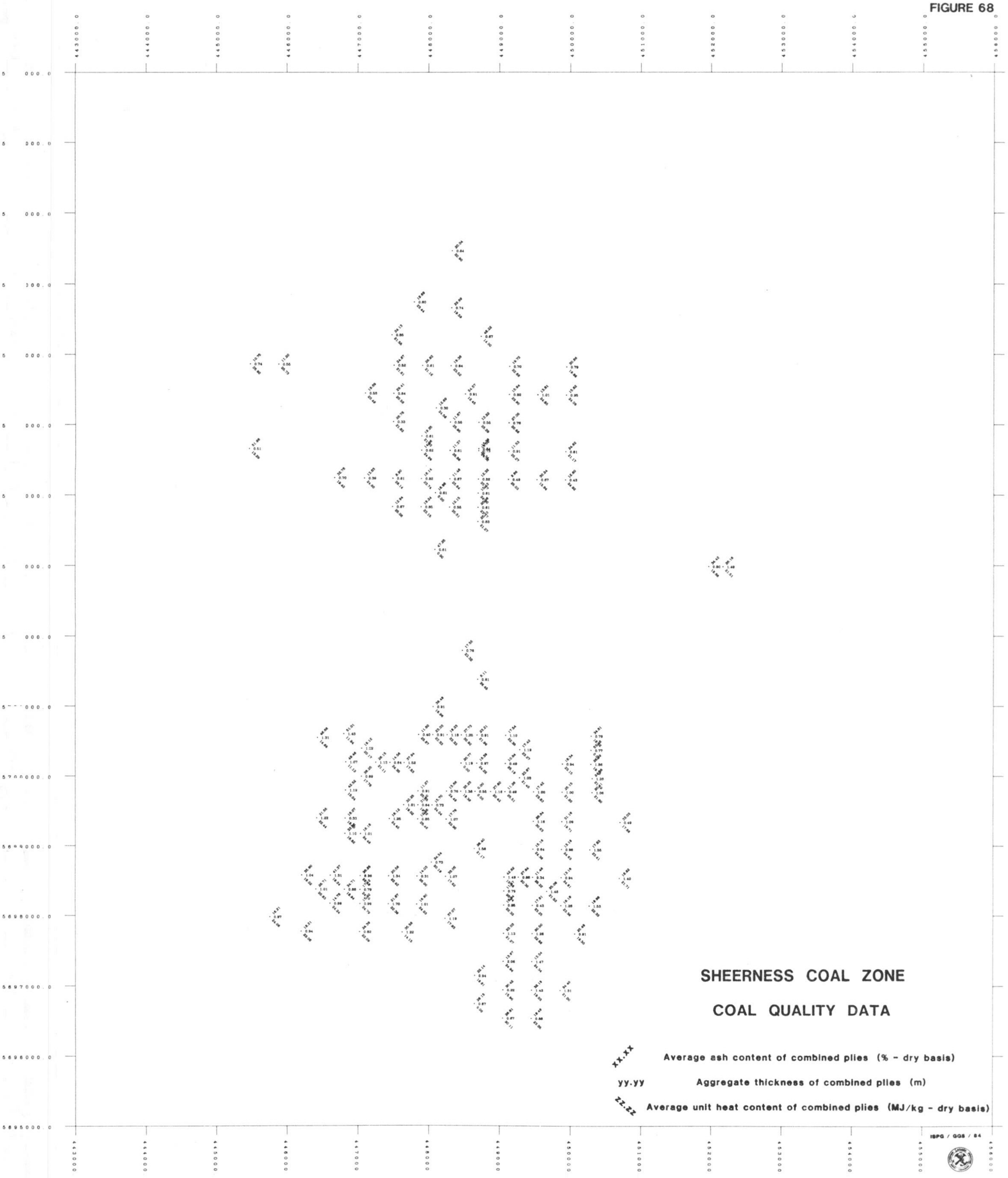
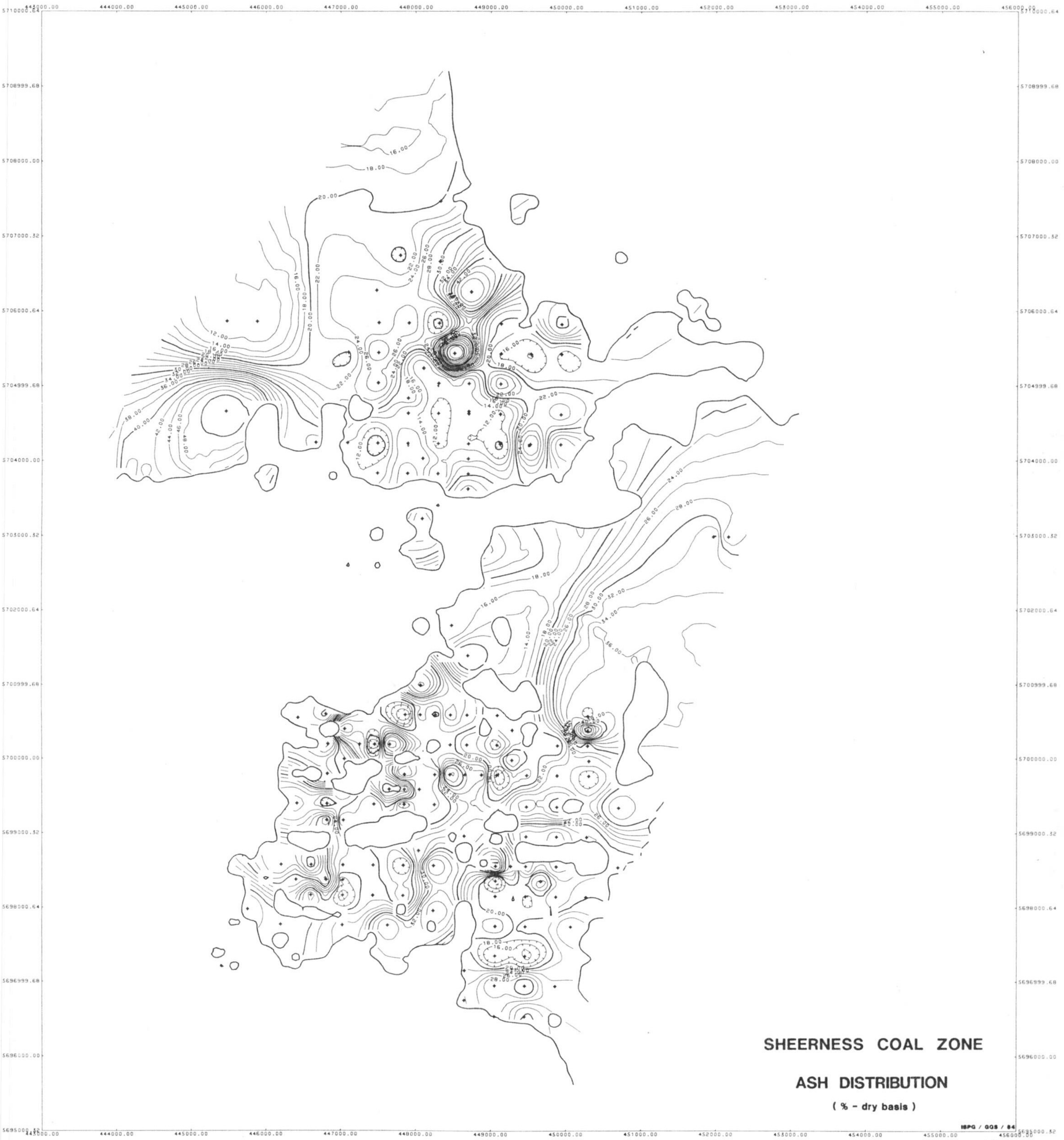

SHEERNESS COAL ZONE
COAL QUALITY DATA
xx.xx Average ash content of combined plies (% - dry basis)
yy.yy Aggregate thickness of combined plies (m)
zz.zz Average unit heat content of combined plies (MJ/kg - dry basis)
ISPG / GGS / 84

FIGURE 69

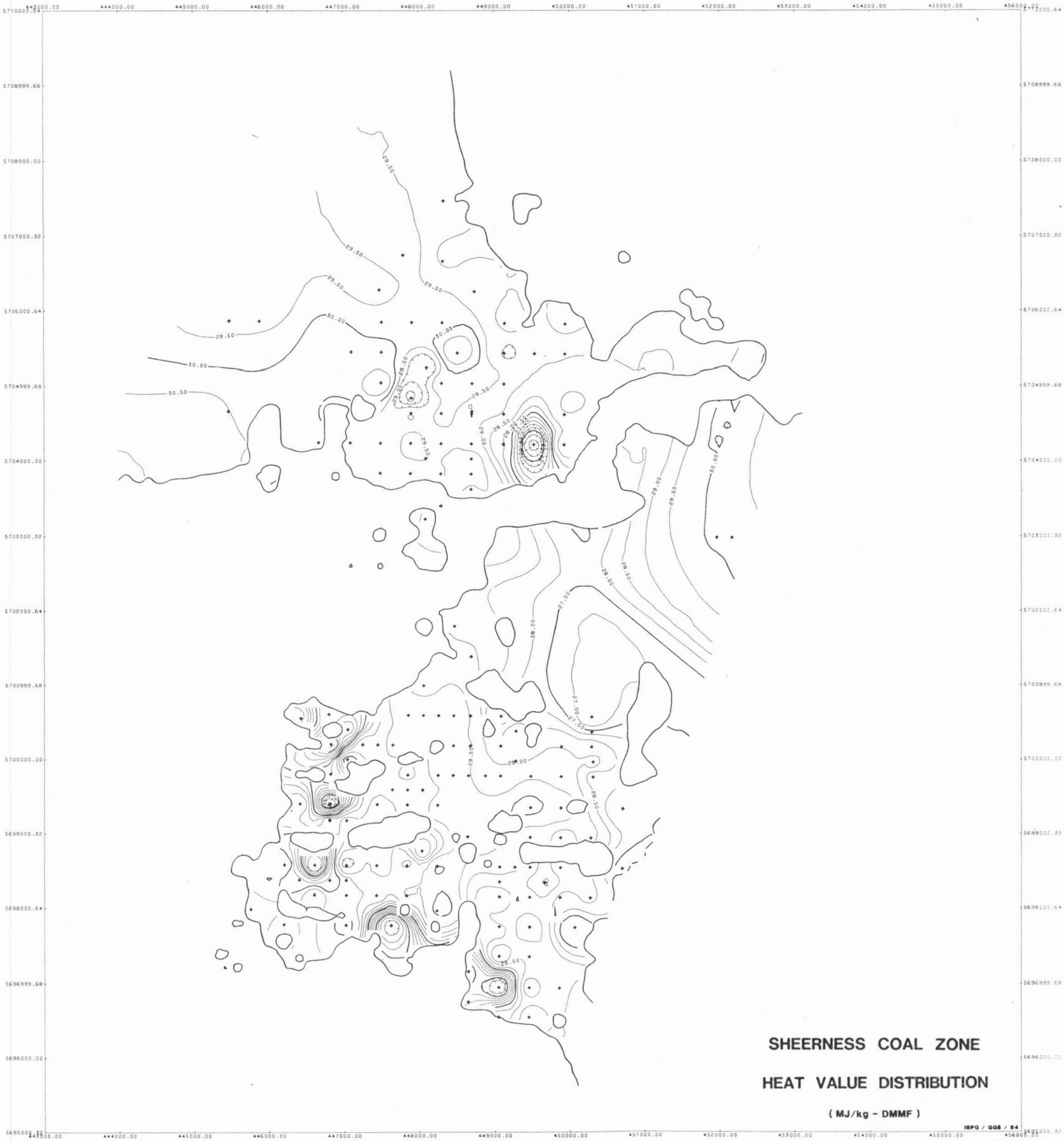


SHEERNESS COAL ZONE

ASH DISTRIBUTION

(% - dry basis)

FIGURE 70



SHEERNESS COAL ZONE

HEAT VALUE DISTRIBUTION

(MJ/kg - DMMF)

FIGURE 71

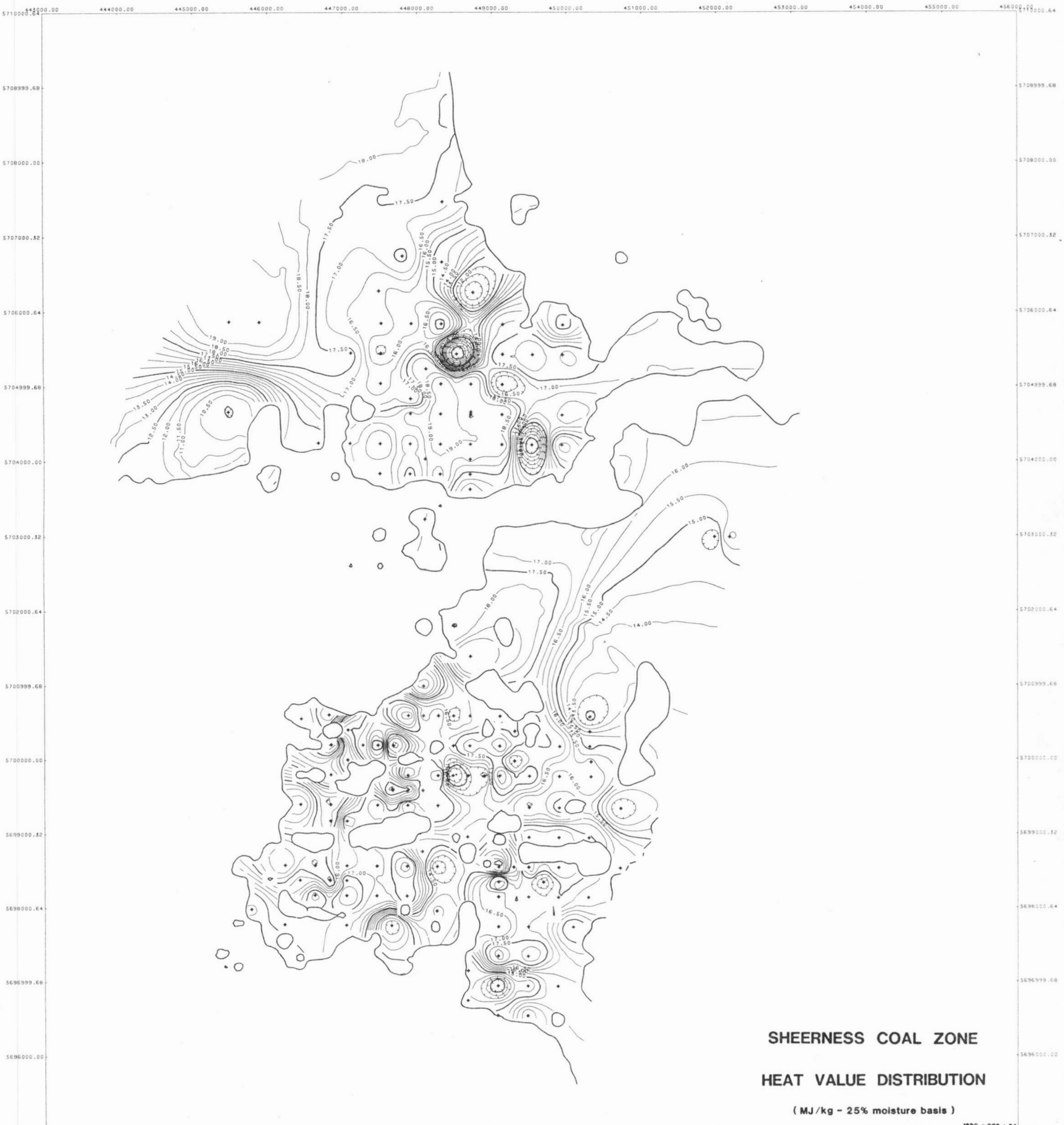
SHEERNESS COAL ZONE

ASH DISTRIBUTION

(% - 25% moisture basis)

ISPG / GGS / 84

FIGURE 72



SHEERNESS COAL ZONE

HEAT VALUE DISTRIBUTION

(MJ/kg - 25% moisture basis)

ISPG / GGS / 84

SHEERNESS-HEAT DISTRIBUTION (@25% MOISTURE)
PLOT NO. 1 DATE OCT 5, 1984 TIME 6:10 PM