DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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SOUTH EASTERN FREEWAY SEISMIC REFRACTION SURVEY - PROPOSED ALIGNMENT, GLEN OSMOND TO CRAFERS

OIL, GAS AND COAL DIVISION

by

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GEOPHYSICS

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DME.55/82

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DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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SOUTH EASTERN FREEWAY SEISMIC REFRACTION SURVEY - PROPOSED ALIGNMENT, GLEN OSMOND TO CRAFERS

ABSTRACT

A total of 27 shallow refraction spreads were recorded over the period from 6.3.87 to 15.4.87 for a total of 2835 metres of traverse, as part of the feasibility study for the realignment of the S.E. Freeway from Glen Osmond to Crafers.

The principal objectives of the survey were:

(i) confirm depth of soil/completely weathered rock
(ii) provide an indication of excavation conditions
(iii) detect geological anomalies

These were achieved in most cases over rocks of the Saddleworth Formation and Stonyfell Quartzite.

For the Saddleworth Formation an average of the velocity determinations was 3520 m/sec with a depth of weathering generally less than 10 metres, while for the Stonyfell Quartzite the average velocity was 2770 m/sec with depths of weathering commonly 15-20 metres.

INTRODUCTION

Maunsell and Partners Pty Ltd of Melbourne were contracted by the South Australian Highways Department to conduct a feasibility study for the re-alignment of the S.E. Freeway from Glen Osmond to Crafers.

At the request of Maunsell and Partners Pty. the Geophysics Branch of the South Australian Department of Mines and Energy conducted a series of shallow seismic refraction traverses, the results of which would be used in conjunction with other site investigations (trenching, drilling, test pits and field mapping) to assist in preliminary design for the selected route.

The objectives of the seismic survey were to:-

i) confirm the depth of soil/completely weathered rock

ii) provide an indication of the excavation conditions

iii) detect geological anomalies such as faults, sheared zones etc.

A total of 27 spreads were recorded in 23 recording days over the period from 6.3.87 to 15.4.87.

GEOLOGICAL SETTING

The regional geology of the study area is shown on the Adelaide 1:50 000 sheet (Forbes, 1980) from which fig. (1) has been adapted.

Seismic spreads were located on one of two formations within the Adelaidean System of rocks, these being the Stonyfell Quartzite and the Saddleworth Formation.

The Stonyfell Quartzite is composed of quartzites and sandstones, while the overlying Saddleworth Formation is composed of green-grey slates and shales with quartzite interbeds (Townsend, 1979).

In general the strata dip 20-40° in an east to south-easterly direction, the siltstones exhibiting a well developed cleavage of variable orientation.

PROCEDURE

A total of 27 refraction spreads were recorded. All spreads were within a nominal 500 metres of access tracks and roads in the area but a certain degree of portability of the equipment was required. All spreads were located in close proximity to the centre line for the proposed alignment.

The seismic spreads consisted of 24 geophones, spaced 5 metres apart with 7 shots detonated per spread. The shots were fired at the centre, midway between the centre and the ends, at the end and at a nominated distance off the end of the spreads. Some 2.5 metre spreads were also recorded (Spreads 27, 23). The energy source was a combination of Anzomex "A" boosters and TOVEX HYDRIVE. (32 mm x 200 mm sticks). Maximum charge size was

36 ozs. but extreme care had to be taken with the charge size to prevent excessive "blow out" of the shot especially when near the freeway. This downgraded some of the results particularly in the bad record areas.

Shot holes were prepared with either a motorized STIHL auger or pick and shovel to depths of 0.5 - 0.7 m.

All records were digitally recorded onto magnetic tape via the Geometrics, Model G-7245 tape recorder to facilitate later computer interpretation of the results.

The seismic records taken were then examined for the first onset of energy, and the times between the shot instant and the "first breaks" were then plotted against the distance from the shot point as time-distance curves. These curves were then analysed using the Generalized Reciprocal Method (G.R.M.) of refraction analysis as outlined by Palmer (1980) to obtain depths and velocities of the rock material below ground surface.

INTERPRETATION

Procedure

Interpretation of results was carried out on a NEC APC III computer. All field recordings were transferred to the computers hard disk on which a software programme adapted from the G.R.M. method of refraction analysis (Palmer 1980) facilitated the picking of first arrivals and interpretation of depths and velocities. All field data and interpretation are now stored on floppy disk.

RESULTS

Interpretations can be largely grouped together based on either subsurface rock type and/or geographic location and groupings of spreads. Because the various sites selected were not recorded in numeric order reference should be made to table 1 which gives the correlation between site number and spread number plus the geographic location.

(a) MT OSMOND AREA (SPREADS 1-5)

All spreads in this area were located on shales and slates of the Saddleworth Foramtion which have near surface exposures as evidenced by the numerous trenches excavated in the area as part

of the planning study. All spreads were located on a spur which trends south-westward toward the Mount Barker Road (see Fig. 2).

Spread 1 & 2 are overlapping spreads and interpretation suggests shallow fresh bedrock with a velocity in excess of 3000 m/sec (fig. 3, 4). Variations in the depth and extent of weathering give rise to the apparent undulations in the fresh bedrock interface.

Spread 3 (fig. 5) also has a fresh bedrock velocity in excess of 3000 m/sec. However, complete mapping of this layer was not possible due to the close proximity of the freeway. Available evidence suggests that the high speed layer is still present beneath the spread but with a slightly greater depth extent. Spreads 4 & 5 are also overlapping spreads and confirm the shallow near-surface velocity of over 3000 m/sec for this particular location (figs 6 & 7).

Again, variations in the depth and extent of weathering associated with different lithologies within the Saddleworth Formation are evident on the interpreted profile.

(b) MT OSMOND TURN OFF (SPREAD 27)

The site was located high above the freeway and was designed to verify the bedrock velocity at this site. Because of the danger of falling rocks onto the road below a 2.5 metre interval spread was used with very low charge sizes. Interpretation indicated a velocity of 3500 m/sec for the Saddleworth Formation at this site with depths to the fresh rock ranging from 3.5 to 9 metres across the spread, shallowing gradually toward the eastern end of the spread (fig. 8).

(c) LEAWOOD GARDENS (SPREAD 25 & 26)

The two spreads recorded at this location were cross-spreads and at the tie point a depth of approximately 10 metres was interpreted to the fresh bedrock with a velocity of 4430 m/sec. A less well defined layer of about 2200 m/sec at approximately 2 metres depth was also interpreted and this is considered to represent a weathered form of the underlying quartzitic rocks (fig 9 & 10).

TABLE 1

D.M.E. SPREAD NOS	AREA	MAUNSELL SITE NOS	DATE RECORDED
1	MT OSMOND	# 1	6.3.87
2	"	# 2	6.3.87
3	MT OSMOND	# 2	9.3.87
4	MT OSMOND	# 3	10.3.87
5	"	# 3	10.3.87
6	SOUTH PORTAL	# 13	12.3.87
7	"	# 12	12.3.87
8	"	# 14	13.3.87
9	NORTH PORTAL	# 8	19.3.87
10	"	# 9	19.3.87
11	EAGLE ON THE HILL	# 17	20.3.87
12	"	# 18	23.3.87
13	"	# 19	24.3.87
14	SAFETY RAMP	# 20	26.3.87
15	MEASEDAY HILL	# 21	27.3.87
16	"	# 23	31.3.87
17	"	# 22	1.4.87
18	"	# 25	3.4.87
20	HILL CREST AVE	# 27	6.4.87
21	CLELAND NAT. PARK	# 29	7.4.87
22	"	# 28	8.4.87
23	"	# 30	9.4.87
24	MEASEDAY HILL	# 26	10.4.87
25	LEAWOOD GARDENS	# 7	13.4.87
26	"	# 6	14.4.87
27	MT OSMOND ROAD	# 4	15.4.87

(d) NORTH PORTAL (SPREAD 9 & 10)

These two spreads were also cross spreads located on slates and quartzites of the Saddleworth Formation. Spread 9 was sited parallel to a trench excavated up a spur and spread 10 was located across the spur.

A single shallow interface is interpreted for the northern two thirds of spread 9 with a velocity of 3750 m/sec (fig. 11) and this is confirmed by the presence of shallow fresh slates in

the adjacent trench. At about geophone 10 a lateral change in rock type is interpreted with a maximum velocity recorded of only 2090 m/sec. This velocity is correlated with the observed shallow subcropping sandstone. The velocity of 2090 m/sec at depths in excess of 10 metres is considered to represent a deep weathered profile within the sandstone.

Results for spread 10 (fig 12) are confused because the spread was located near to the contact between the slate and the quartzite and would appear to run parallel to it. Results suggest that the weathered profile associated with the sandstone is present on both the eastern and western ends of the spread while a high velocity of 4270 m/sec correlated with the slates is present in the centre of the spread and deepening to the east.

(e) SOUTH PORTAL SPREADS (6,7,8)

Spreads 6 & 7 are also tied together, with spread 6 sited along an access track subparallel to the surface contours, while spread 7 ran straight down the contours.

Interpretation for these two spreads was made difficult due to the apparent lack of continuity in the subsurface refractors. Variations in amount of weathering and/or a lateral rock type change is thought to be responsible for the change from a velocity of 2380 m/sec. at a depth of 8 - 10 metres on the western end of spread 6 to a velocity of 4440 m/sec at 3 metres depth at the eastern end (fig. 13). The bedrock velocity of 4400 m/sec was considered a little high when compared to neighbouring results but is confirmed at the tie with spread 7 (fig. 14).

Spread 8 was located immediately to the east of spread 7 but still on rocks of the Saddleworth Formation. Bedrock velocities of only 3080 m/sec and greater depths of weathering 12-18 metres were identified. Velocities within this weathered zone ranged from 2200 - 2500 m/sec. (fig. 15).

(f) EAGLE ON THE HILL (SPREADS 11 & 12)

Spreads 11 and 12 were cross spreads located on the downhill slopes opposite the Eagle on the Hill Hotel, in near vicinity of the Clarenden Fault.

Weathering effects are indicated to extend to variable depths of up to 20 metres on the southern end of spread 11. Similar depths were found on spread 12.

Maximum bedrock velocities of 3390 m/sec. were obtained on spread 12. This layer was not detected on spread 11 due to limitations in offset distances placed upon the survey because of the closeness of the freeway.

Velocities in the weathered zones vary from 1500 - 2500 m/sec and occur to within 3 metres of the surface at most points along the spreads (figs. 16,17).

(g) MEASEDAY HILL (SPREADS 13, 14,15,16,17)

These spreads are all located on hill slopes around Measeday Hill (refer fig. 2). All spreads were located on a very weathered gritty sandstone and results from all spreads suggest deep weathering profiles.

For spread 13 & 14 (fig. 18,19), depths of 12 - 15 metres to a velocity interface of 2140 m/sec. suggest that the weathering continues significantly deeper in that no fresh bedrock interface was able to be mapped.

For spreads 15 - 17 depths to fresh bedrock (velocity 3000 - 3500 m/sec) are between 15 and 25 metres on the downhill ends of the spread. In all cases fresh bedrock appears to become shallower at the uphill end of the spreads (fig. 20, 21, 22).

(h) MEASEDAY HILL (SPREADS 18, 19)

Spreads 18 and 19 were located close to one another on a steep north-facing slope composed of very weathered sandstone. Results for both spreads were very similar bedrock velocity estimate of 2450 and 2490 m/sec. respectively, and with depths to that layer of approximately 10 metres for spread 18 (fig. 23) and 10 - 14 metres at the southern end of spread 19 and increasing to 15 - 20 metres at the downhill northern end (fig. 24). An intermediate layer of 2120 m/sec was interpreted for spread 19 with variable depths from 3 to 10 metres.

(i) SPREAD 24

Also located on a steep north facing slope, spread 24 was sited on an apparent fresh, massive quartzite outcrop. Interpretation (fig. 25) gave one single velocity of 2740 m/sec. at the shallow depth of approximately 2 metres.

(j) HILLCREST AVE SPREAD 20

Spread 20 was located on slates and shales of the Saddleworth Formation. Fresh bedrock was near-outcropping and this was confirmed by the interpretation of a bedrock velocity of 3140 m/sec. at depths variable between 2 - 6 metres across the spread (fig. 26).

(k) CLELAND NATIONAL PARK (SPREADS 21,22, 23)

All 3 spreads were located along tracks within the Cleland National Park and investigated rocks of the Saddleworth Formation.

Spreads 21 and 22 tied and gave bedrock velocities of 3580 and 3240 m/sec at less than 6 metres depth (fig 27,28), while for spread 23 a velocity of 3040 m/sec at depths ranging from 3 - 7 metres is correlated with fresh bedrock (fig. 29).

CONCLUSION AND RECOMMENDATIONS

The shallow seismic refraction survey was successful in defining depth of soils and in most cases was able to estimate the depth to and velocity of fresh bedrock.

Of the 27 spreads, 19 were nominally over rocks of the Saddleworth Formation while 8 were over the Stoneyfell Quartzite.

For the Saddleworth Formation an average of the maximum velocites observed was 3520 m/sec with a range of 2810-4440 m/sec. Weathering effects were generally restricted to less than 10 metres depth and fresh bedrock was detected in all cases.

For the Stonyfell Quartzite, however, weathering effects were generally much more pronounced with depths of 15 - 20 metres indicated in some cases and in others the depth to a fresh rock

interface was not mapped at all. The average of the maximum velocities recorded for the Stonyfell Quartzite was 2770 m/sec with a velocity range of 2140-4015 m/sec.

The lower velocities and depths of 15-20 metres of unconsolidated material recorded at some of the sites over the Stonyfell Quartzite may represent different engineering problems compared to the Saddleworth Formation and may require special attention as far as slope stability and method of excavation.

It was found that with a 5 metre geophone interval the layers within the weathered zone were not satisfactorily mapped. In order to facilitate this an interval of 2.5 metres is recommended for future of surveys. This would be most applicable when considering excavation and foundation conditions at specific sites at a later stage in the study.

It is recommended that for a full appraisal of the proposed road alignment further seismic refraction data be collected and in areas of marginal velocity where excavation is likely a test ripping program be conducted to "calibrate" the seismic velocities. However, standard rippability vs seismic velocity charts may assist in the initial appraisal.

REFERENCES

1. FORBES, B.G., 1980. Adelaide map sheet, Geological Atlas of South Australia, 1:50 000 series Geol. Surv. S. Aust.

2. PALMER, D., 1980. The Generalized reciprocal Method of Seismic Refraction Interpretation, Society of Exploration Geophysicists Tusa, Oklahoma.

3. TOWNSEND, I.J., 1979 The Geology of the Eagle Quartzite Quarry. Mineral Resources Rev., S. Aust., 180: 31 - 38.

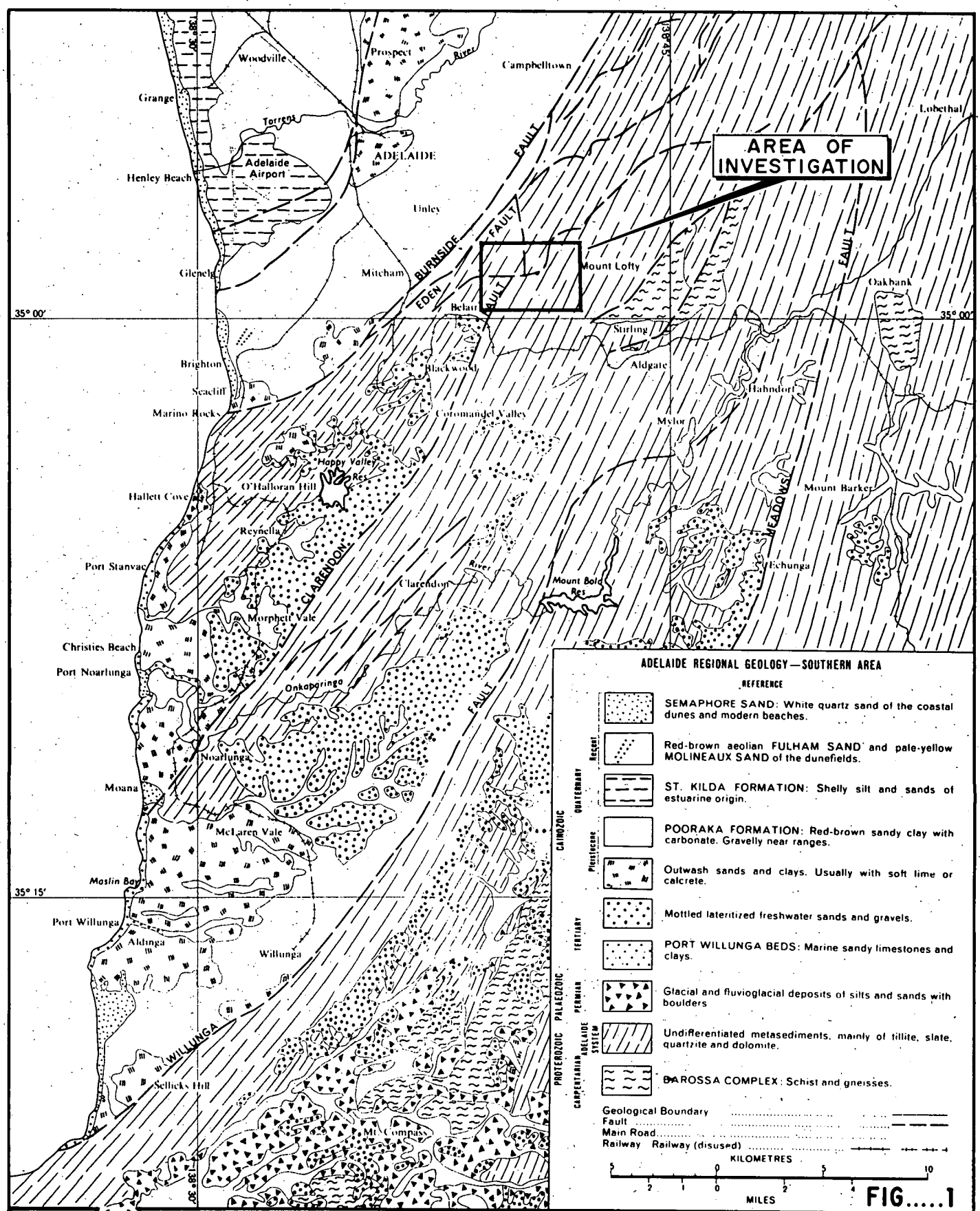

FIG.....1

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DRAWN R. Bird	SCALE 1: 250000
DATE July 1987	PLAN NUMBER S19386
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SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
LOCALITY PLAN

4422

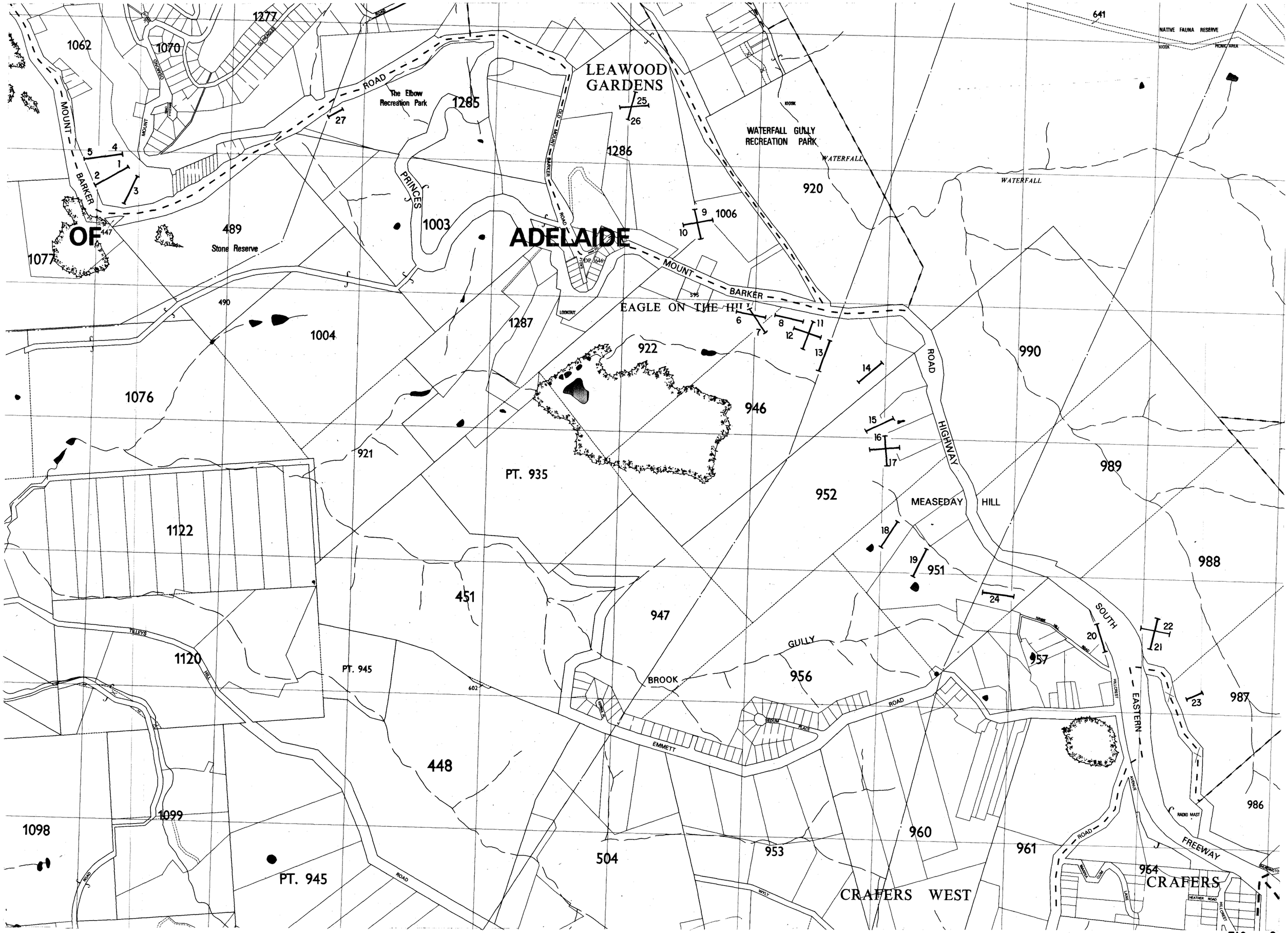

FIG.....2

19 Spread Number

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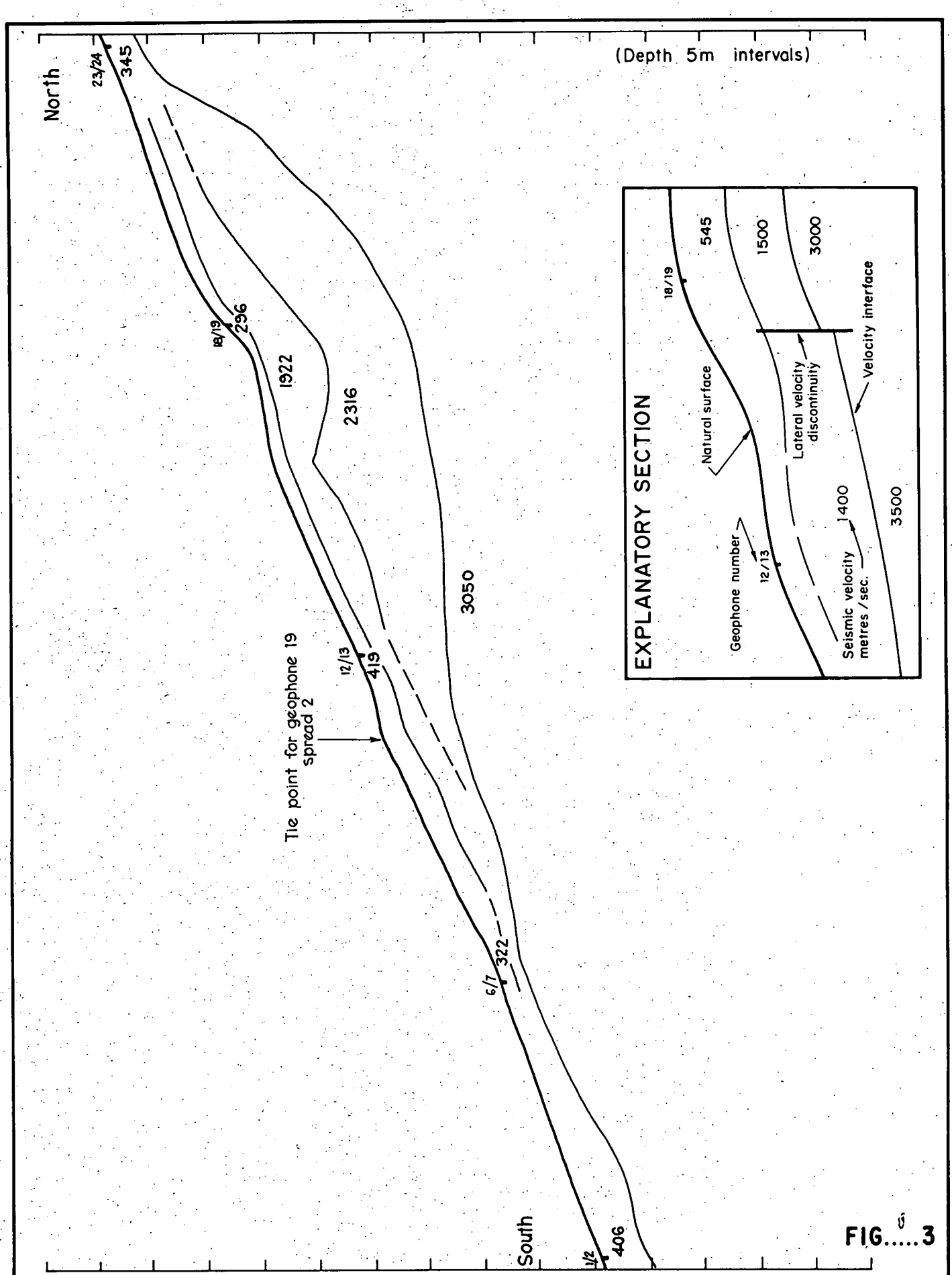

FIG.....3

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SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 1 SPREAD 1

COMPILED P. Hough	C.D.O. 21·7·87 DATE
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DATE 9-7-87	PLAN NUMBER S 19359
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4422

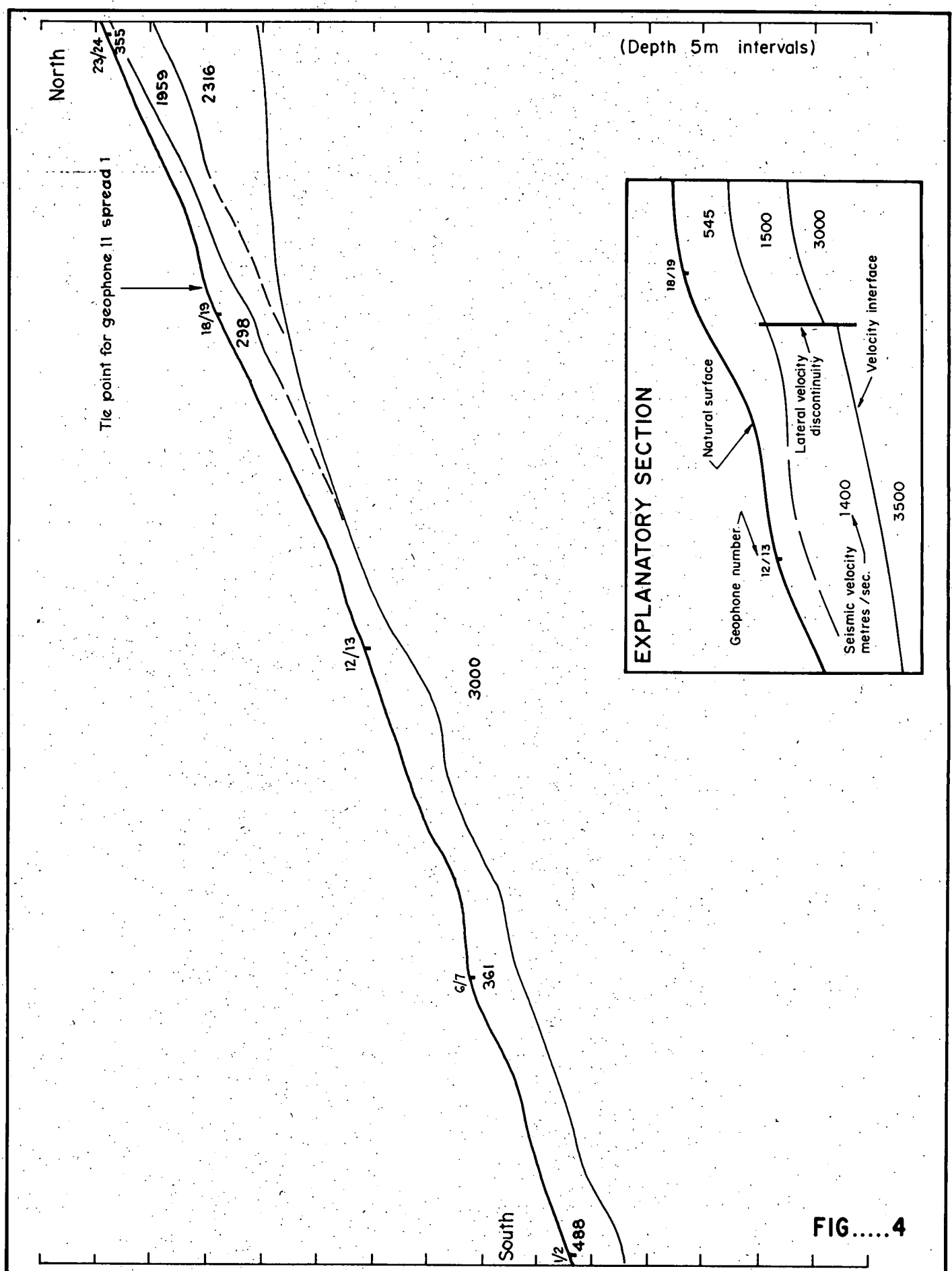

FIG.....4

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DATE 9-7-87

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PLAN NUMBER S19360

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 1 SPREAD 2

4422

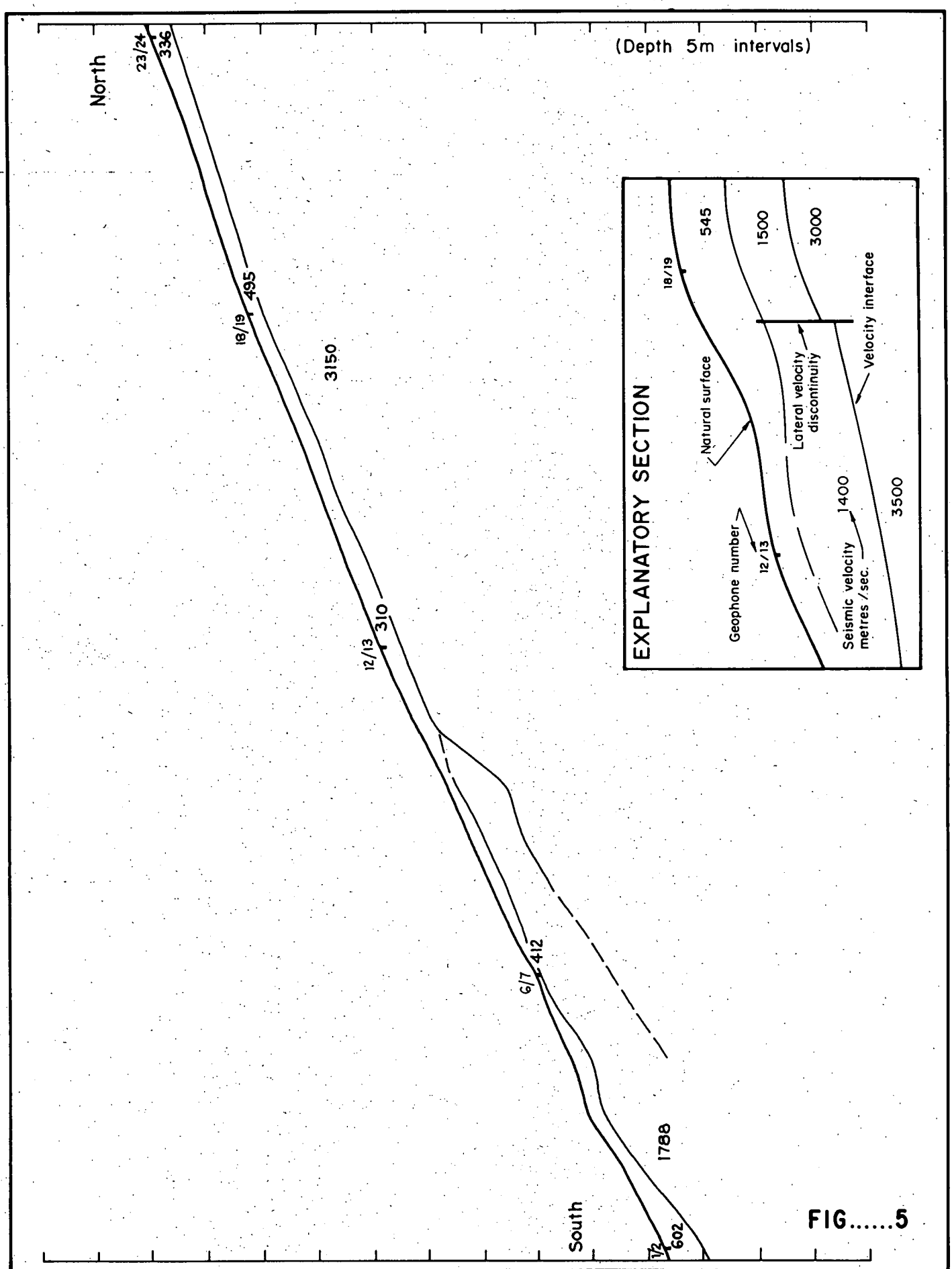

FIG.....5

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SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 2 SPREAD 3

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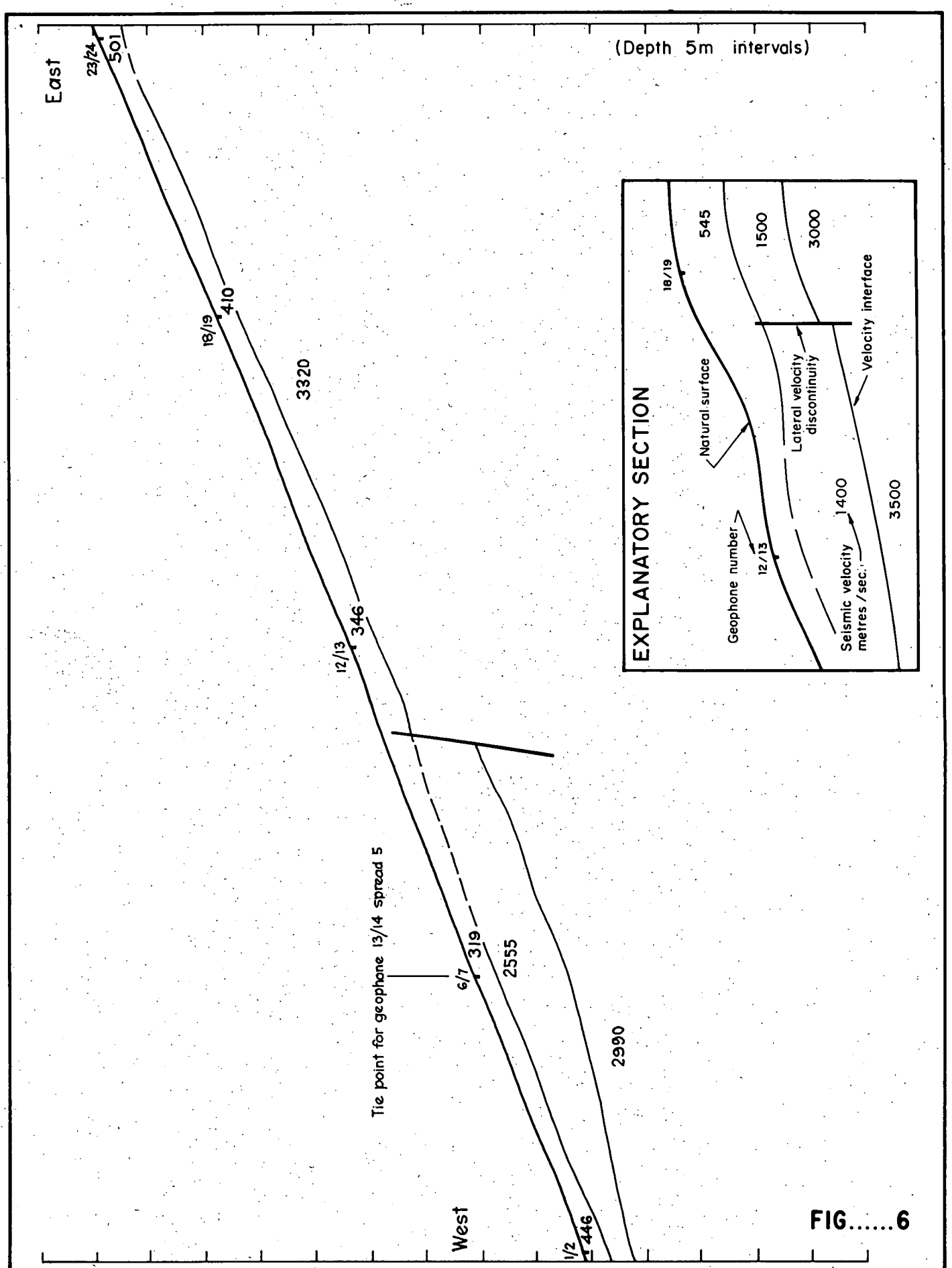

FIG.....6

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SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 3 SPREAD 4

4422

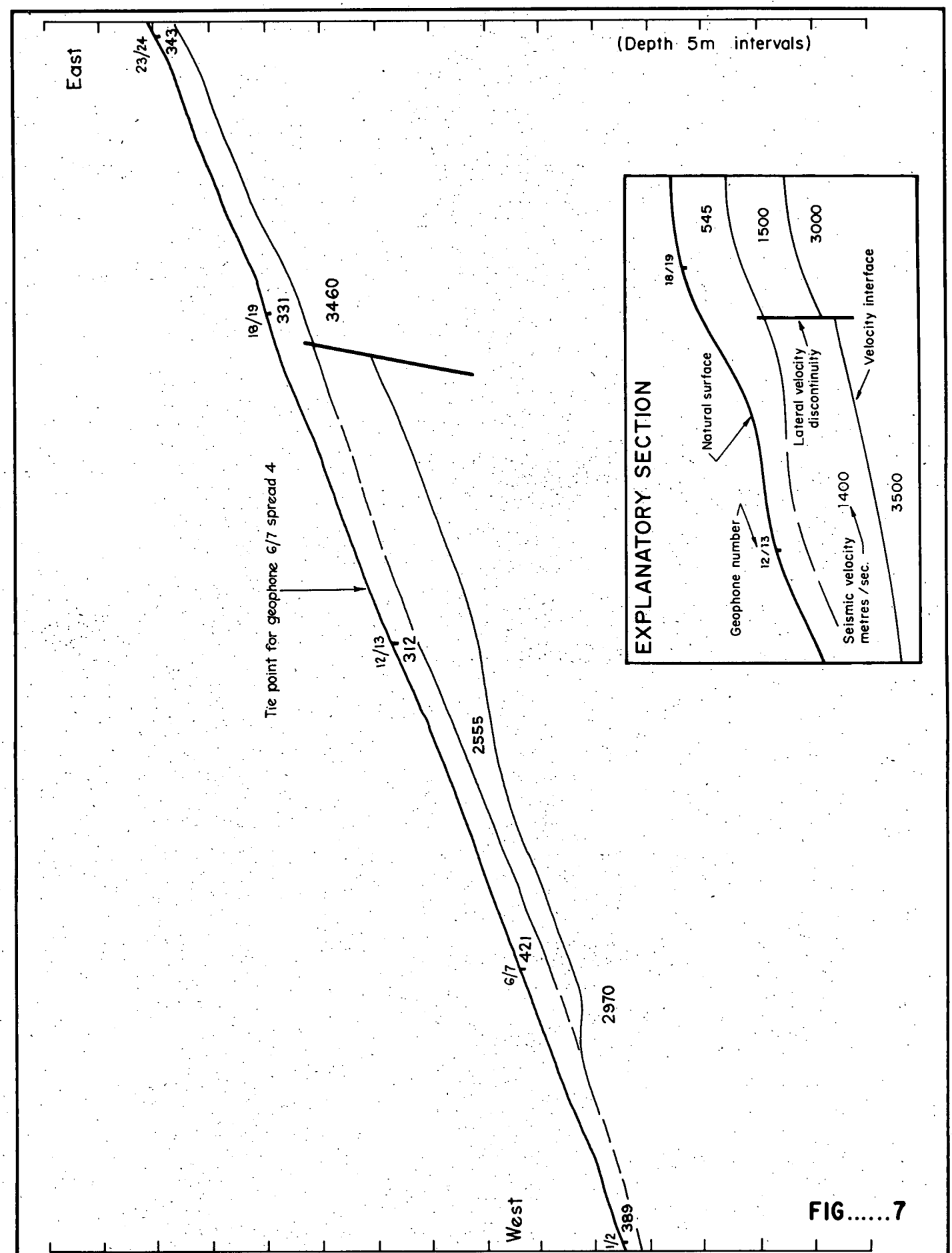

FIG.....7

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DATE 9-7-87

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PLAN NUMBER S19363

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 3 SPREAD 5

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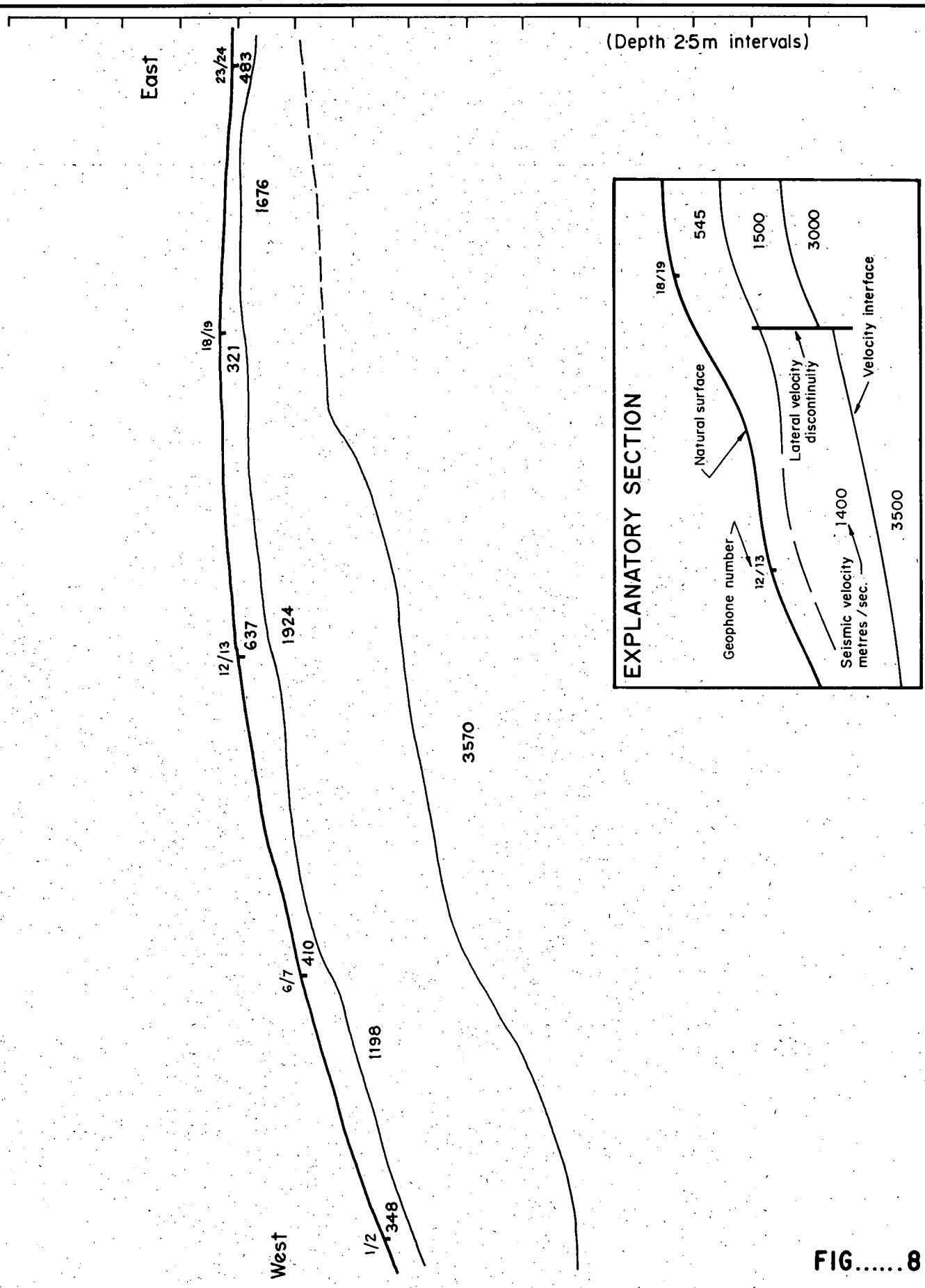

FIG.....8

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SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 4 SPREAD 27

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DATE 9-7-87	PLAN NUMBER S19364
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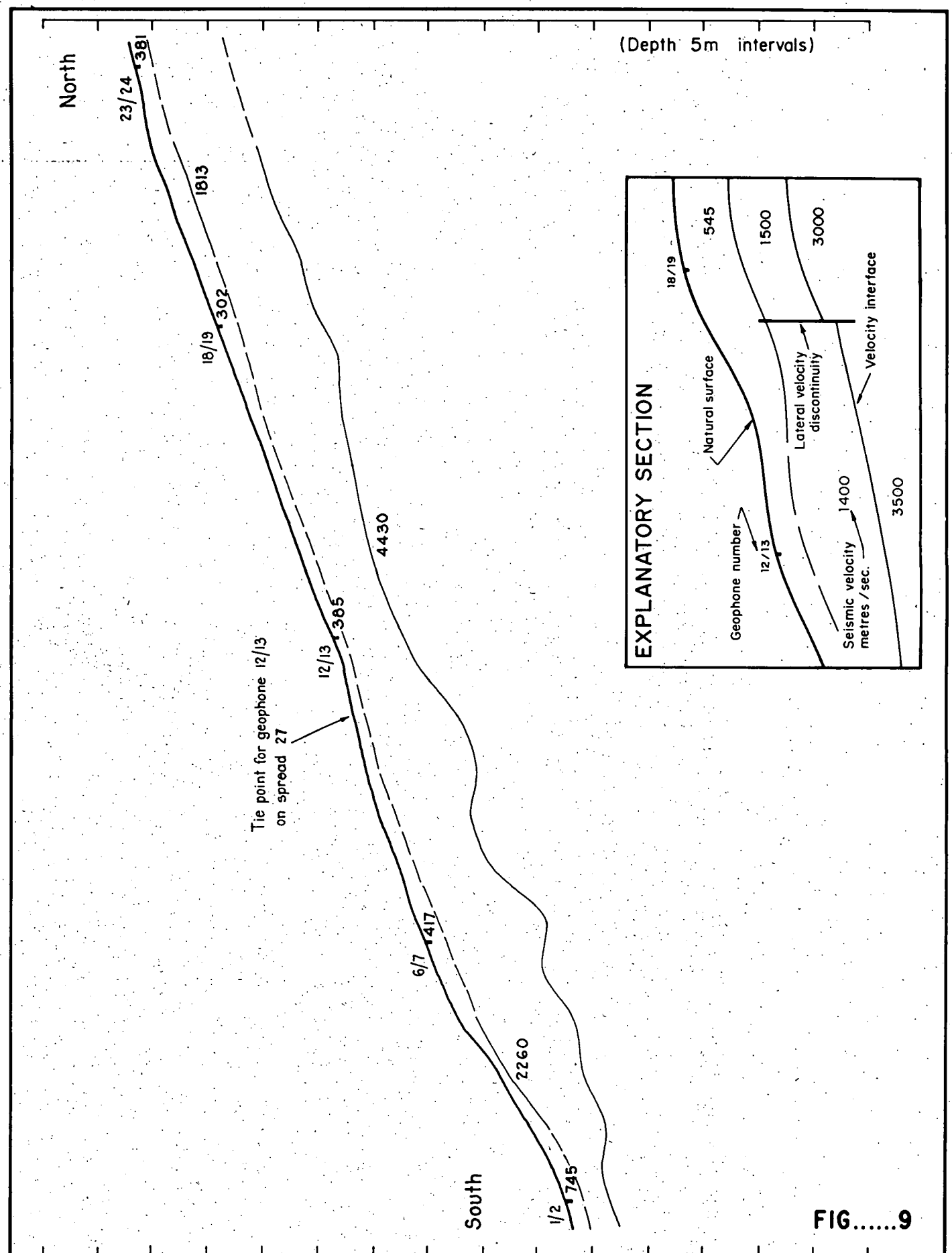

FIG.....9

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SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 6 SPREAD 26

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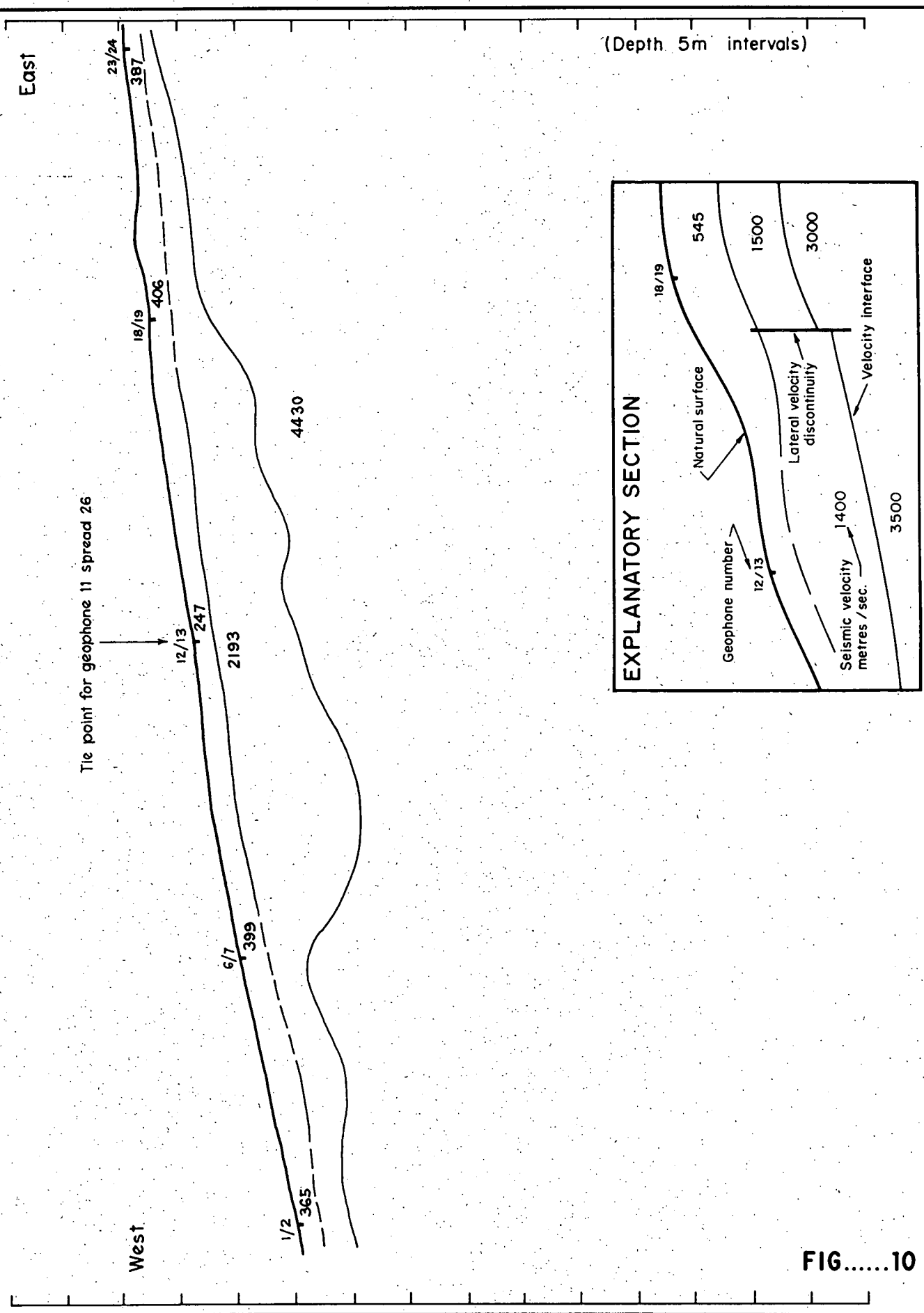

FIG.....10

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SOUTH EASTERN FREEWAY SEISMIC STUDY GLEN OSMOND – CRAFERS SECTION SITE 7 SPREAD 25	DRAWN A.F.	SCALE 1:500	
	DATE 9-7-87	PLAN NUMBER S19366	
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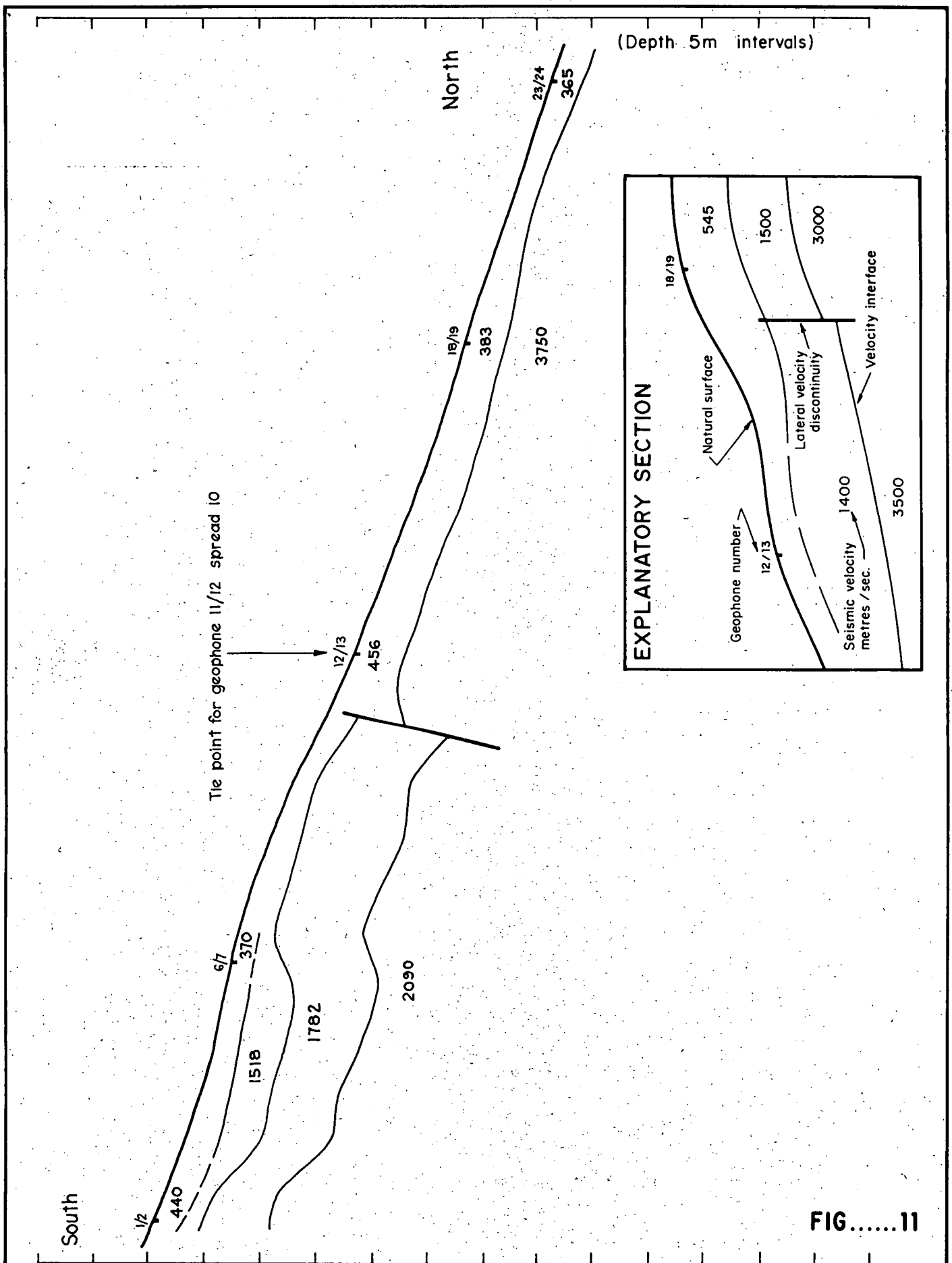

FIG.....11

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SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 8 SPREAD 9

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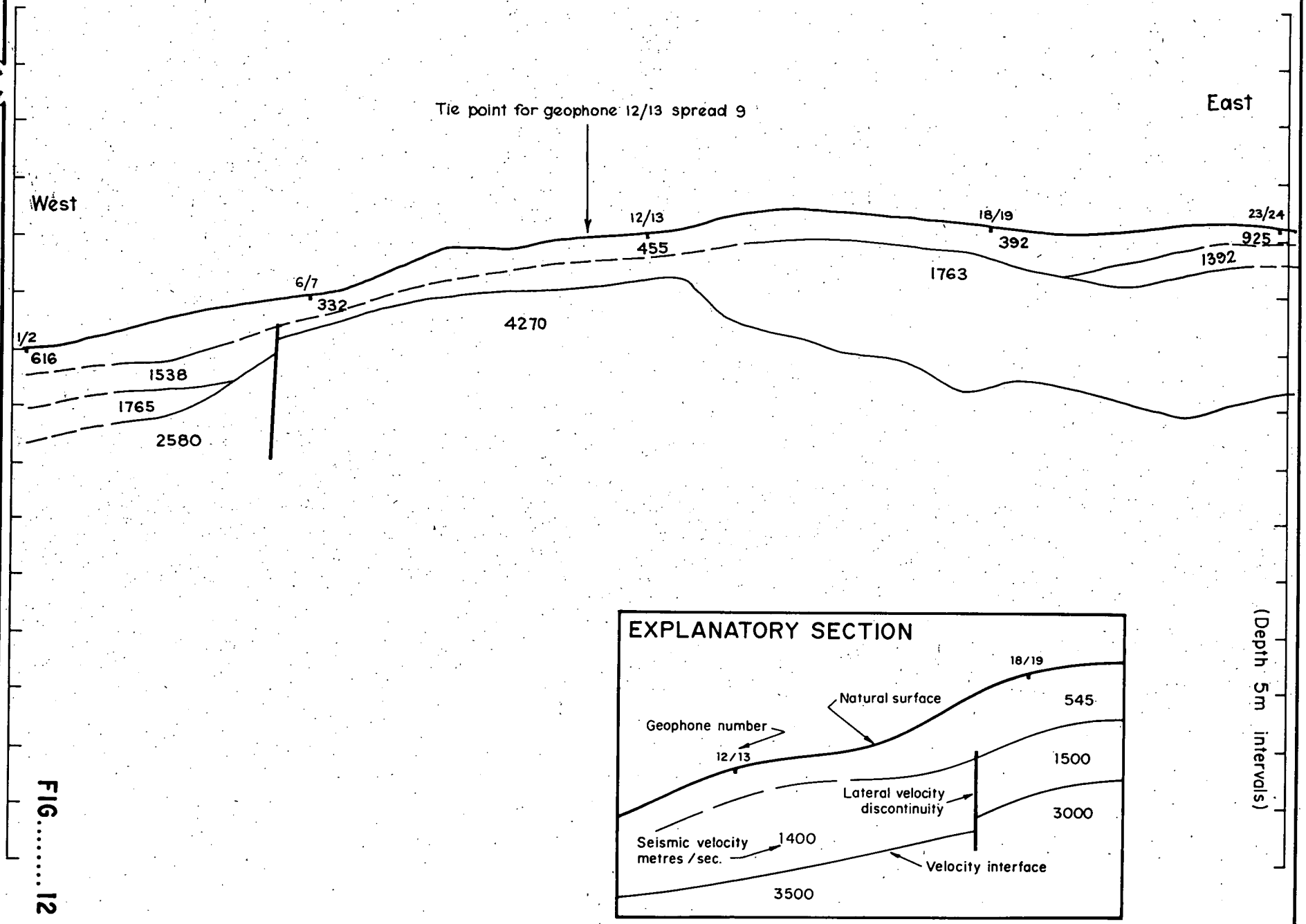

FIG.....12

SOUTH EASTERN FREEWAY SEISMIC STUDY

GLEN OSMOND – CRAFERS SECTION

SITE 9 SPREAD 10

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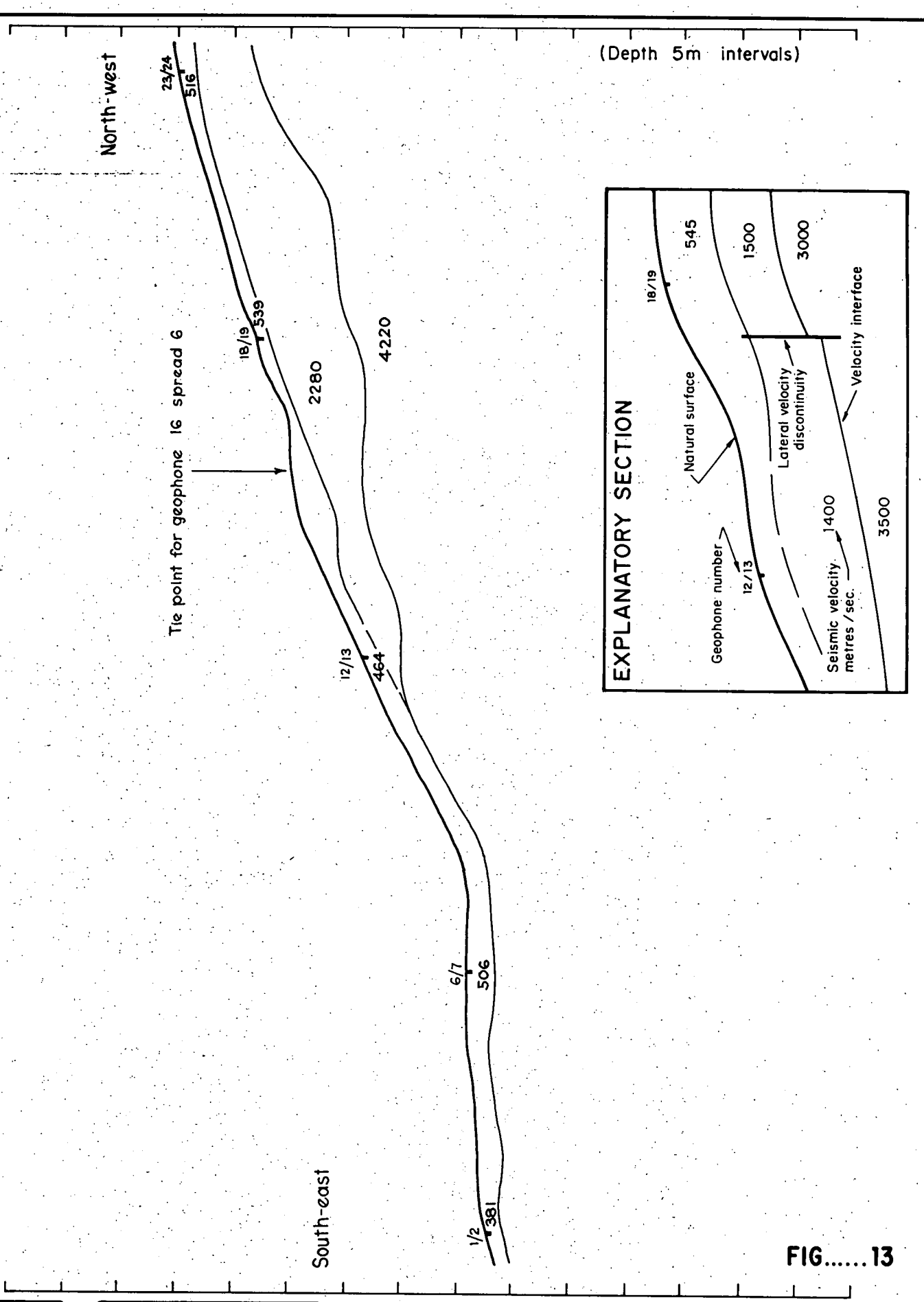

FIG.....13

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SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 12 SPREAD 7

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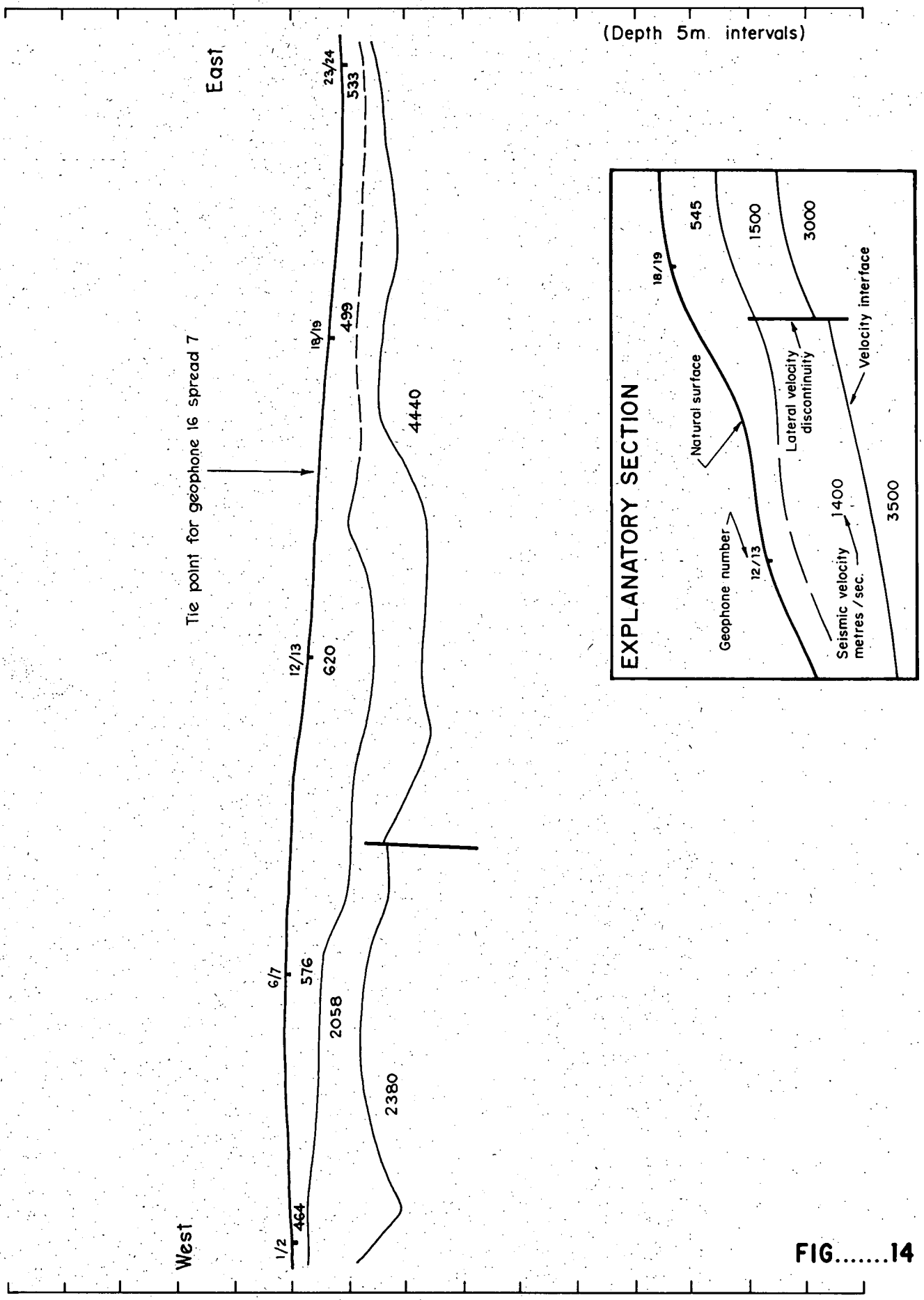

FIG.....14

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DATE 9-7-87

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PLAN NUMBER S 19370

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 13 SPREAD 6

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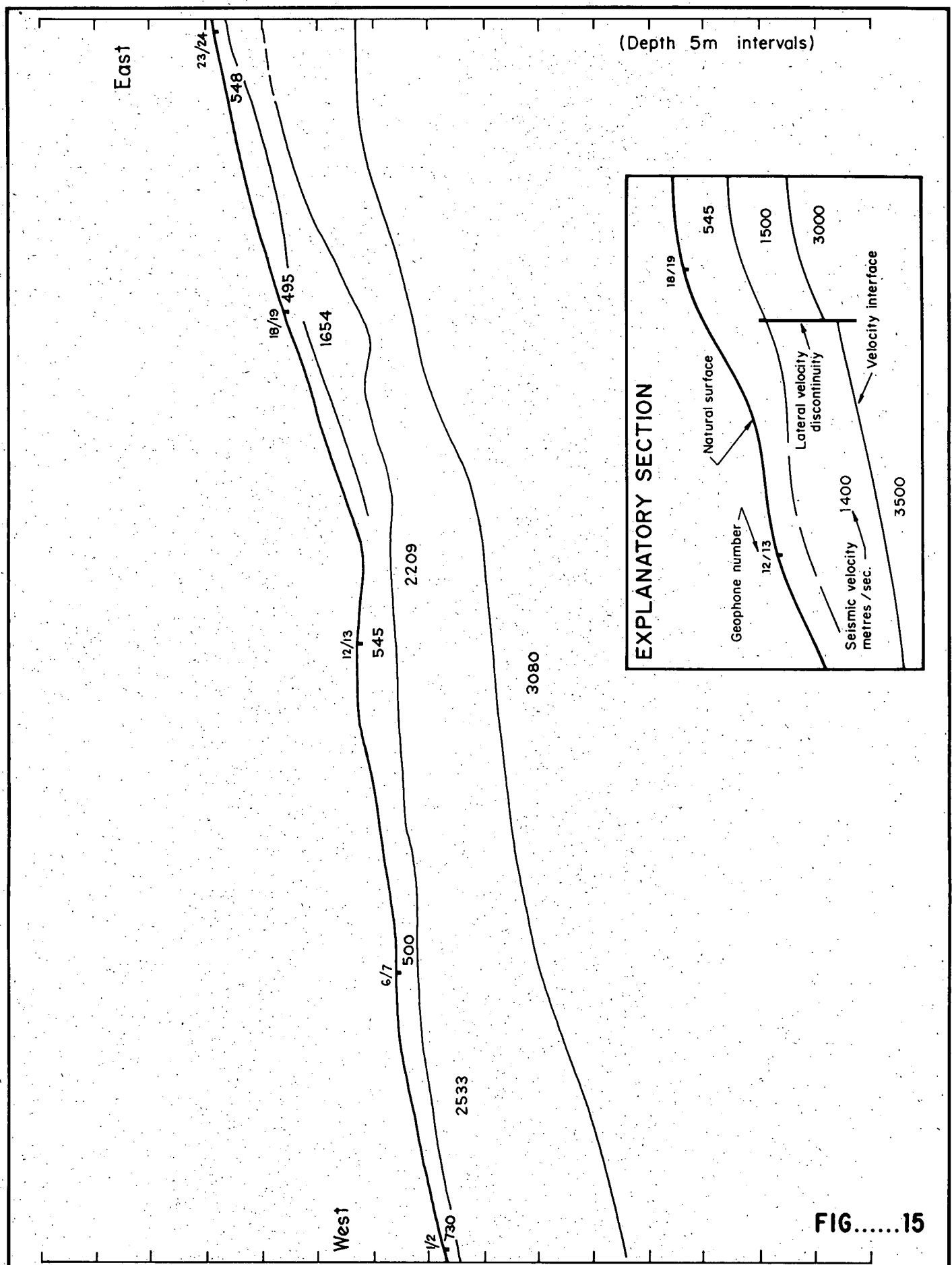

FIG.....15

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DATE 9-7-87

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PLAN NUMBER S 19371

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 14 SPREAD 8

4422

4422

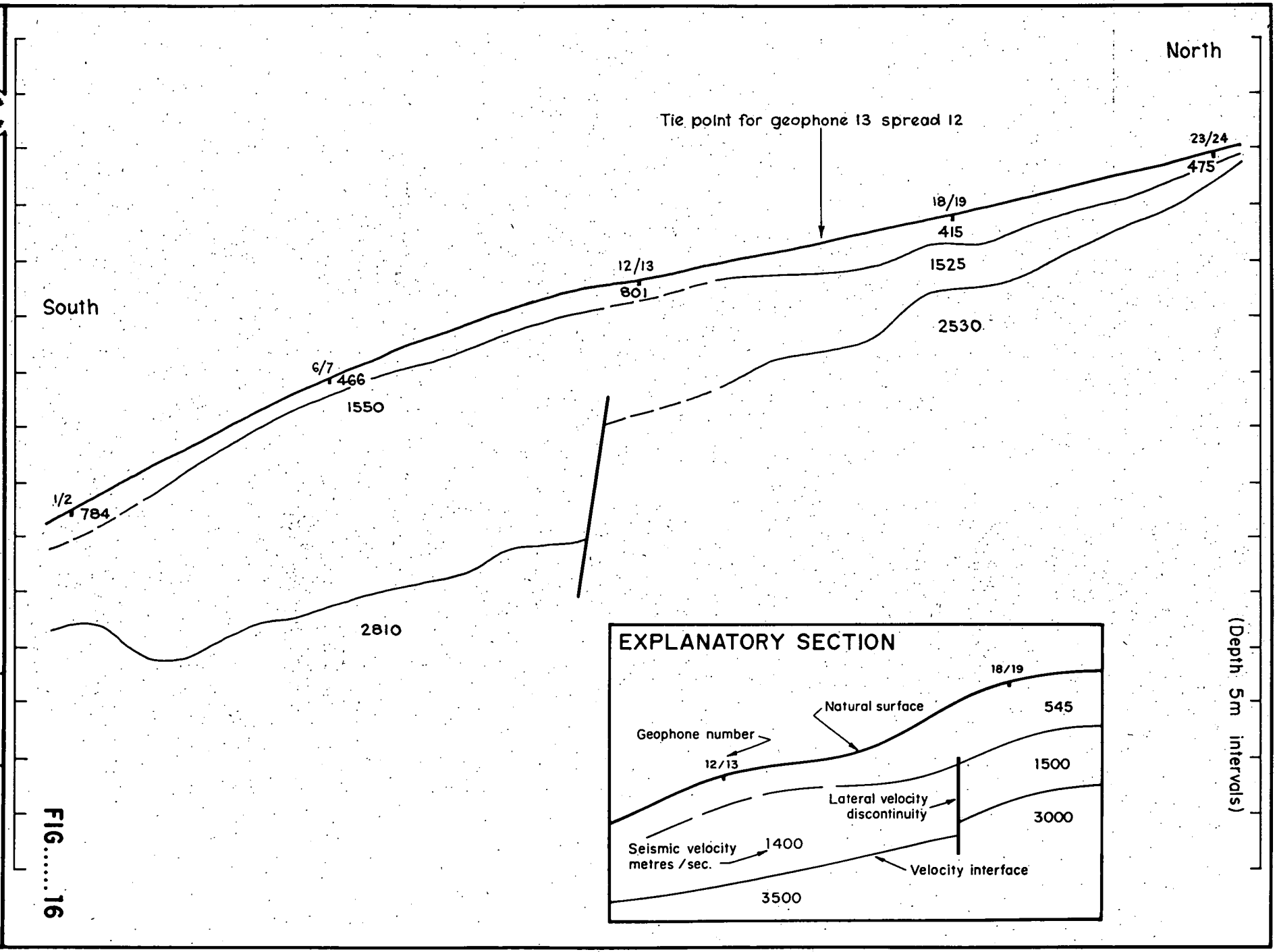

FIG.....16

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SOUTH EASTERN FREEWAY SEISMIC STUDY

GLEN OSMOND – CRAFERS SECTION

SITE 17 SPREAD 11

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SCALE 1:500			
C.D.O. 21·7·87 DATE	PLAN NUMBER S19372		

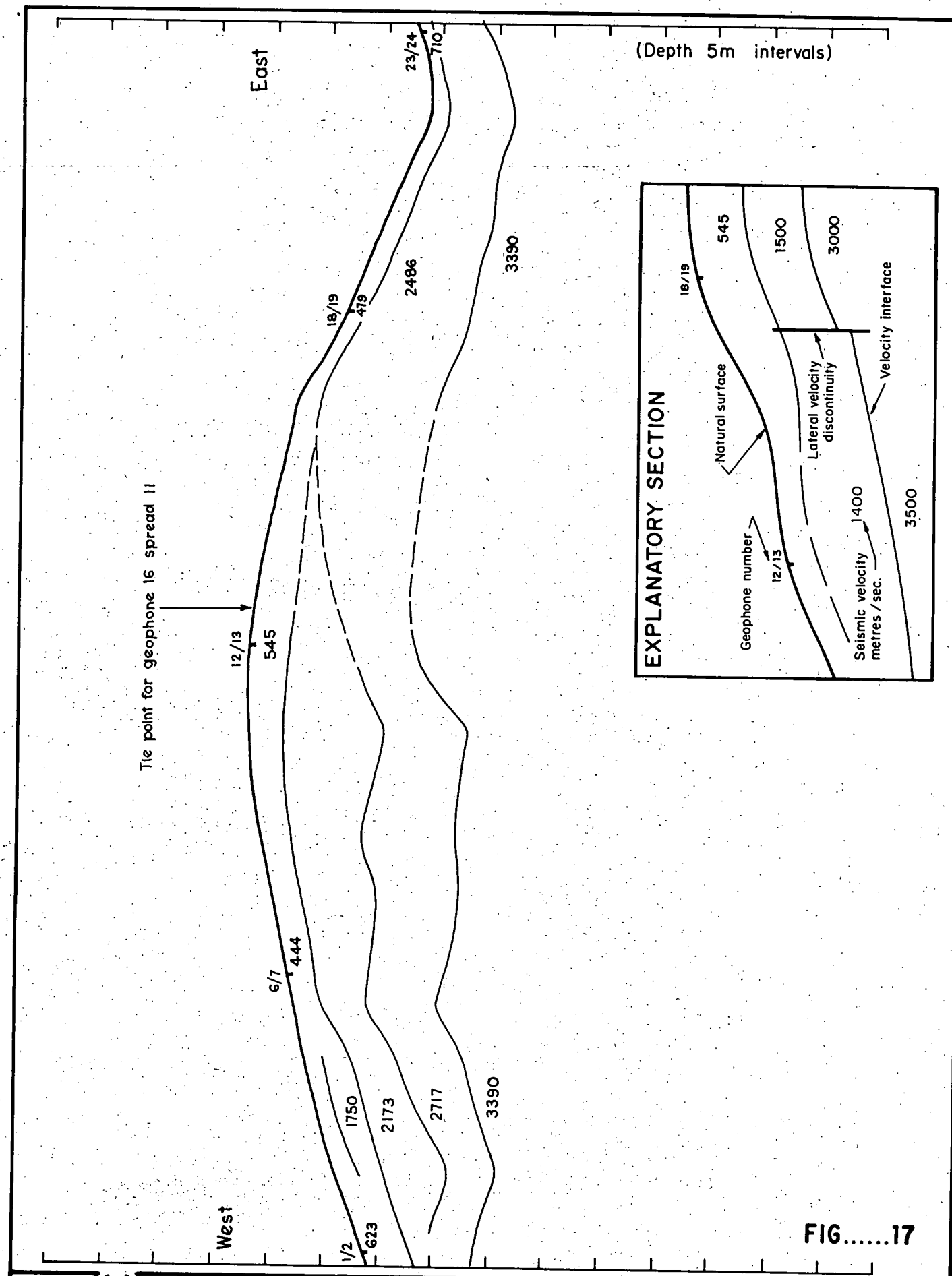

FIG.....17

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 18 SPREAD 12

COMPILED P. Hough	C.D.O. 21·7·87 DATE
DRAWN A.F.	SCALE 1:500
DATE 9-7-87	PLAN NUMBER S 19373
CHECKED	

4422

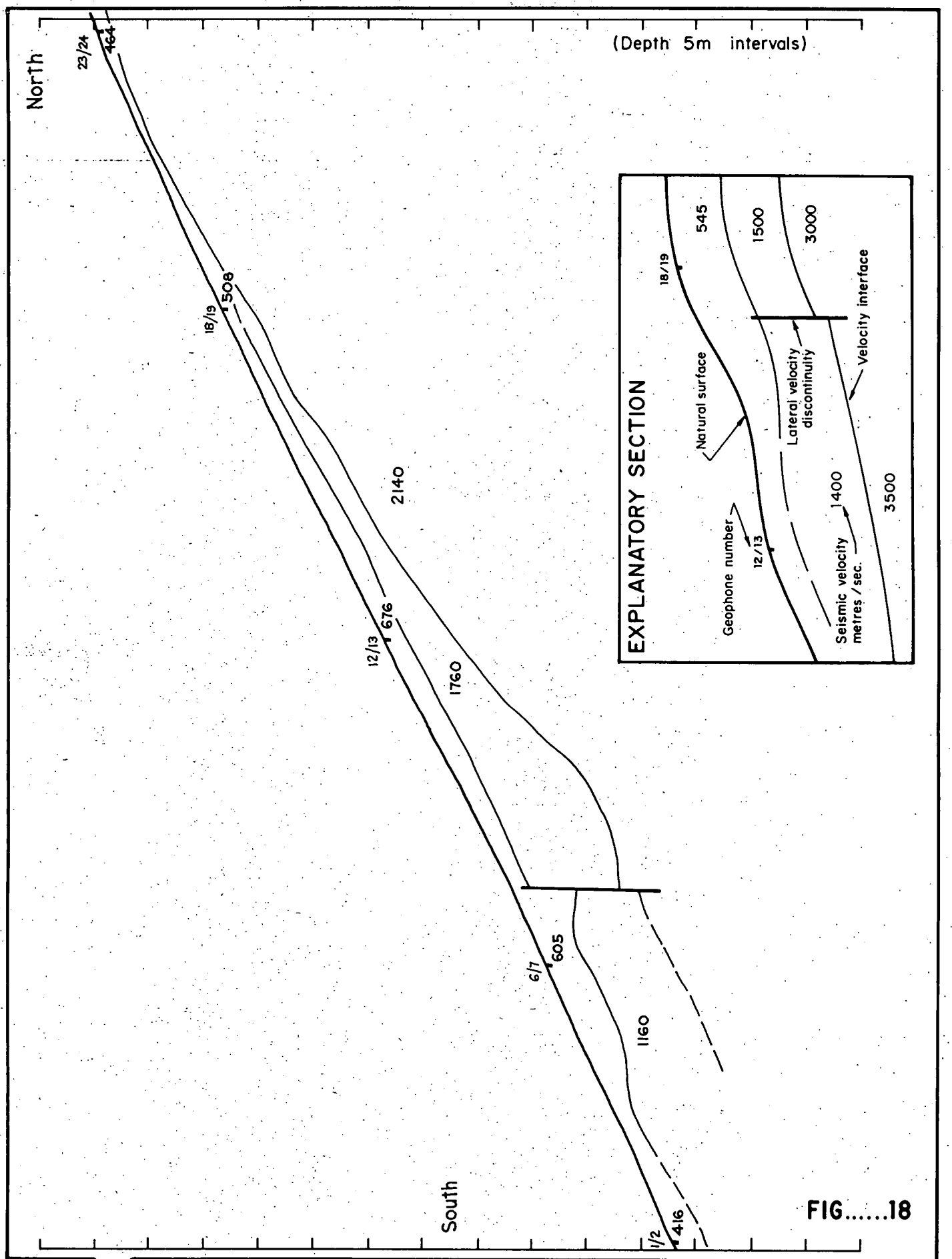

FIG.....18

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 19 SPREAD 13

COMPILED P. Hough	C.D.O. 21-7-87 DATE
DRAWN A.F.	SCALE 1:500
DATE 9-7-87	PLAN NUMBER
CHECKED	S 19374

4422

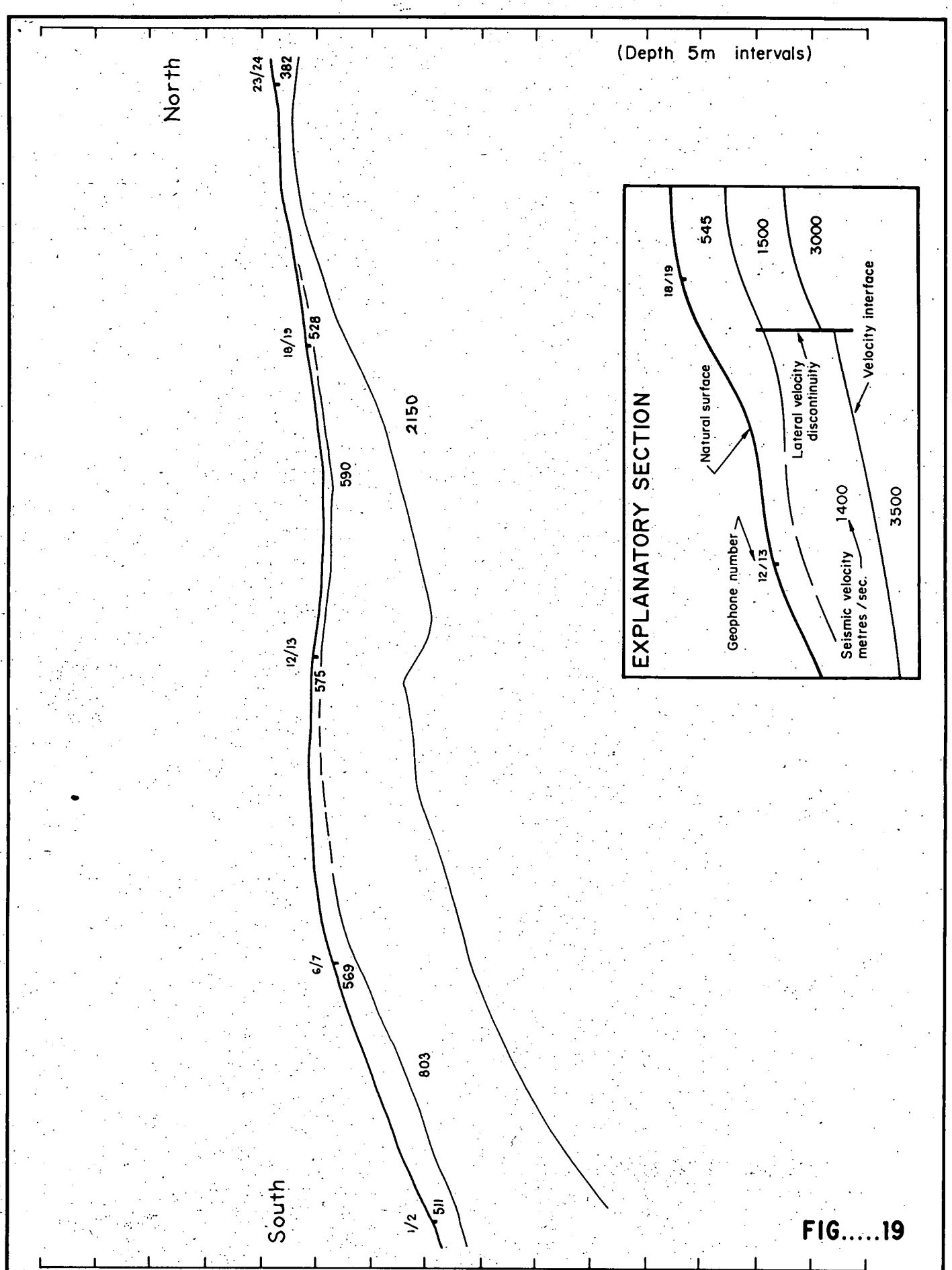

FIG.....19

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 20 SPREAD 14

COMPILED P. Hough	C.D.O. 21·7·87 DATE
DRAWN A.F.	SCALE 1:500
DATE 9-7-87	PLAN NUMBER S 19375
CHECKED	

4422

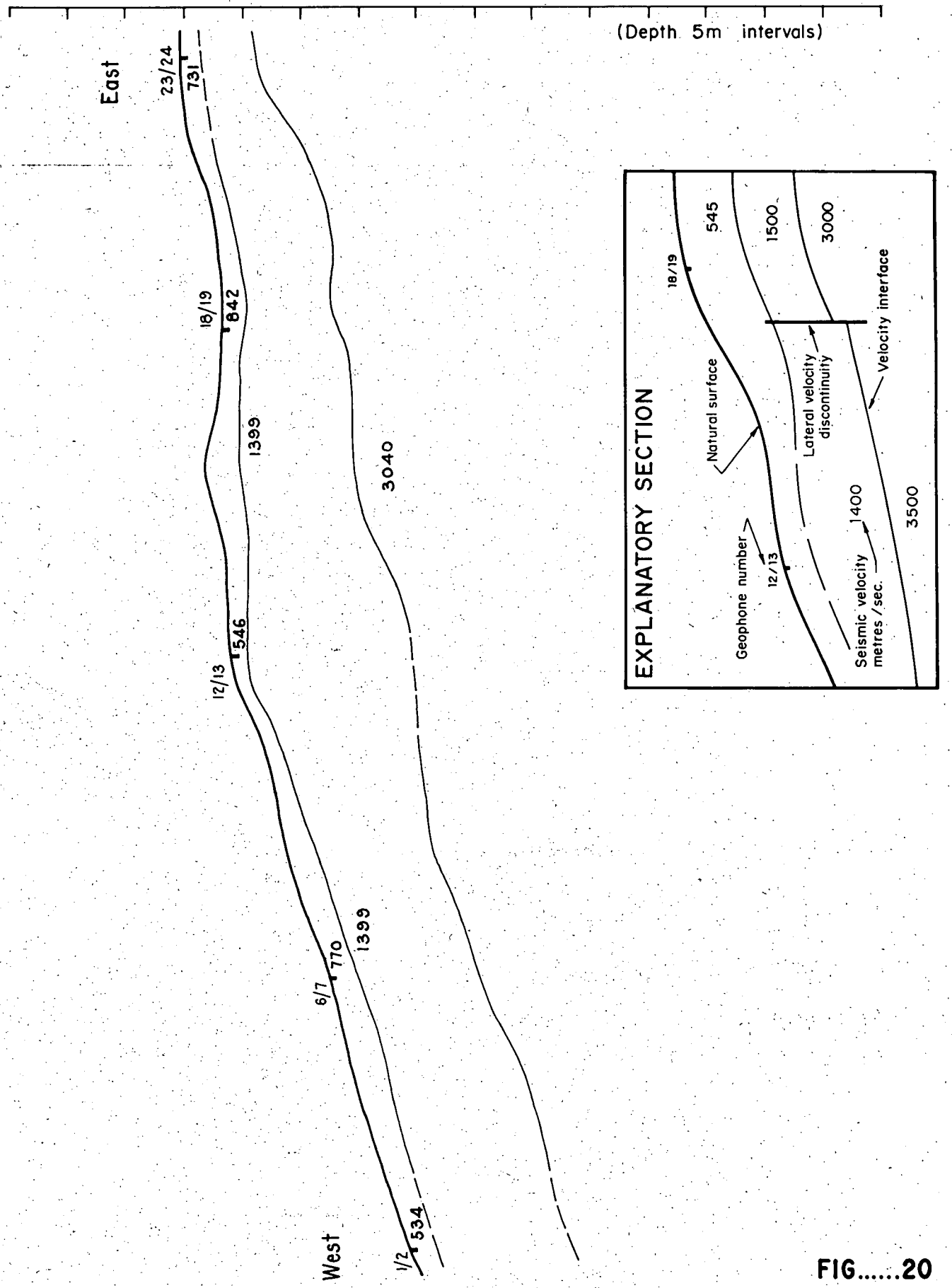

FIG.....20

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 21 SPREAD 15

COMPILED P. Hough	C.D.O. 21·7·87 DATE
DRAWN A.F.	SCALE 1:500
DATE 9-7-87	PLAN NUMBER S 19376
CHECKED	

4422

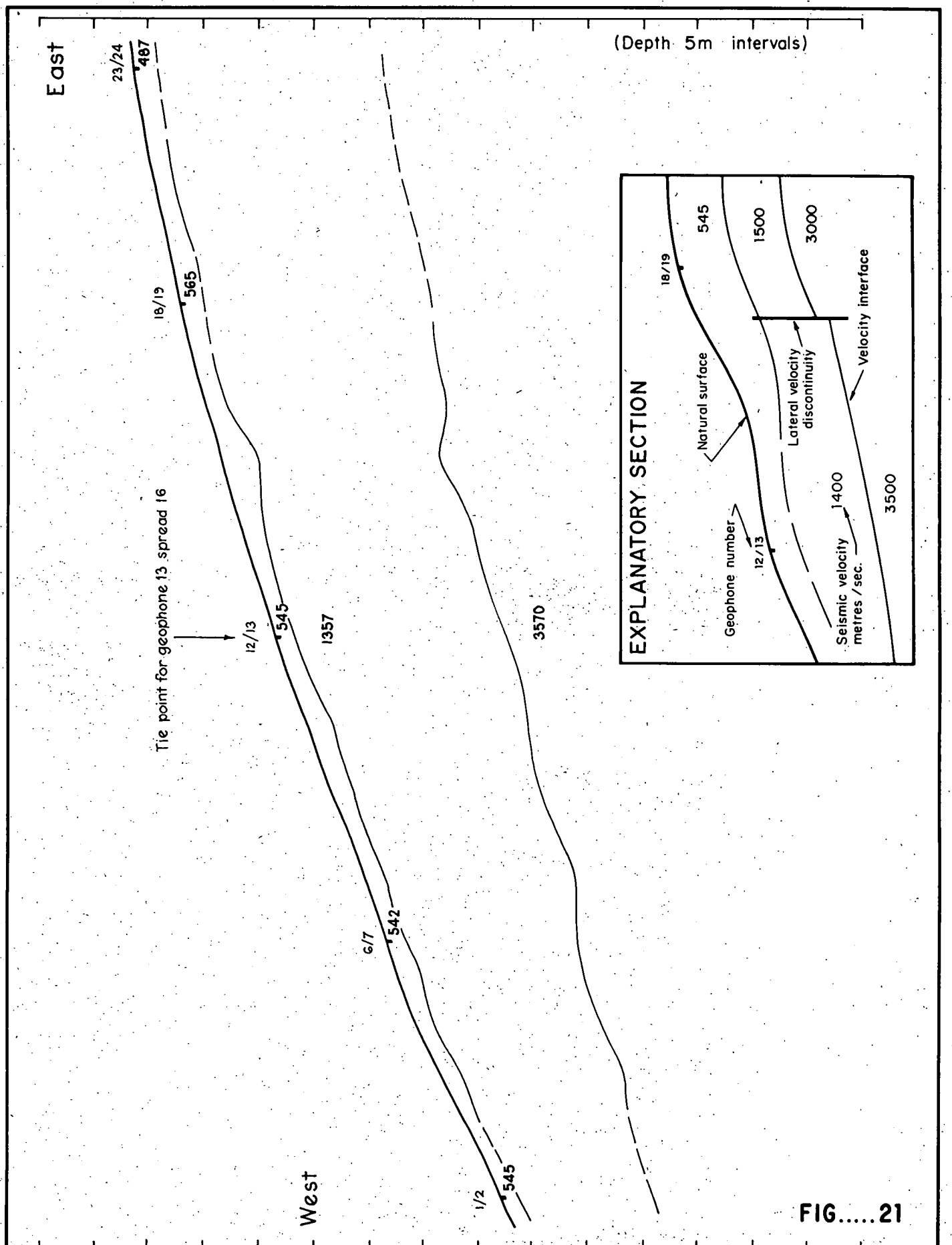

FIG.....21

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 22 SPREAD 17

COMPILED P. Hough	C.D.O. 21·7·87 DATE
DRAWN A.F.	SCALE 1:500
DATE 9-7-87	PLAN NUMBER
CHECKED	S 19377

4422

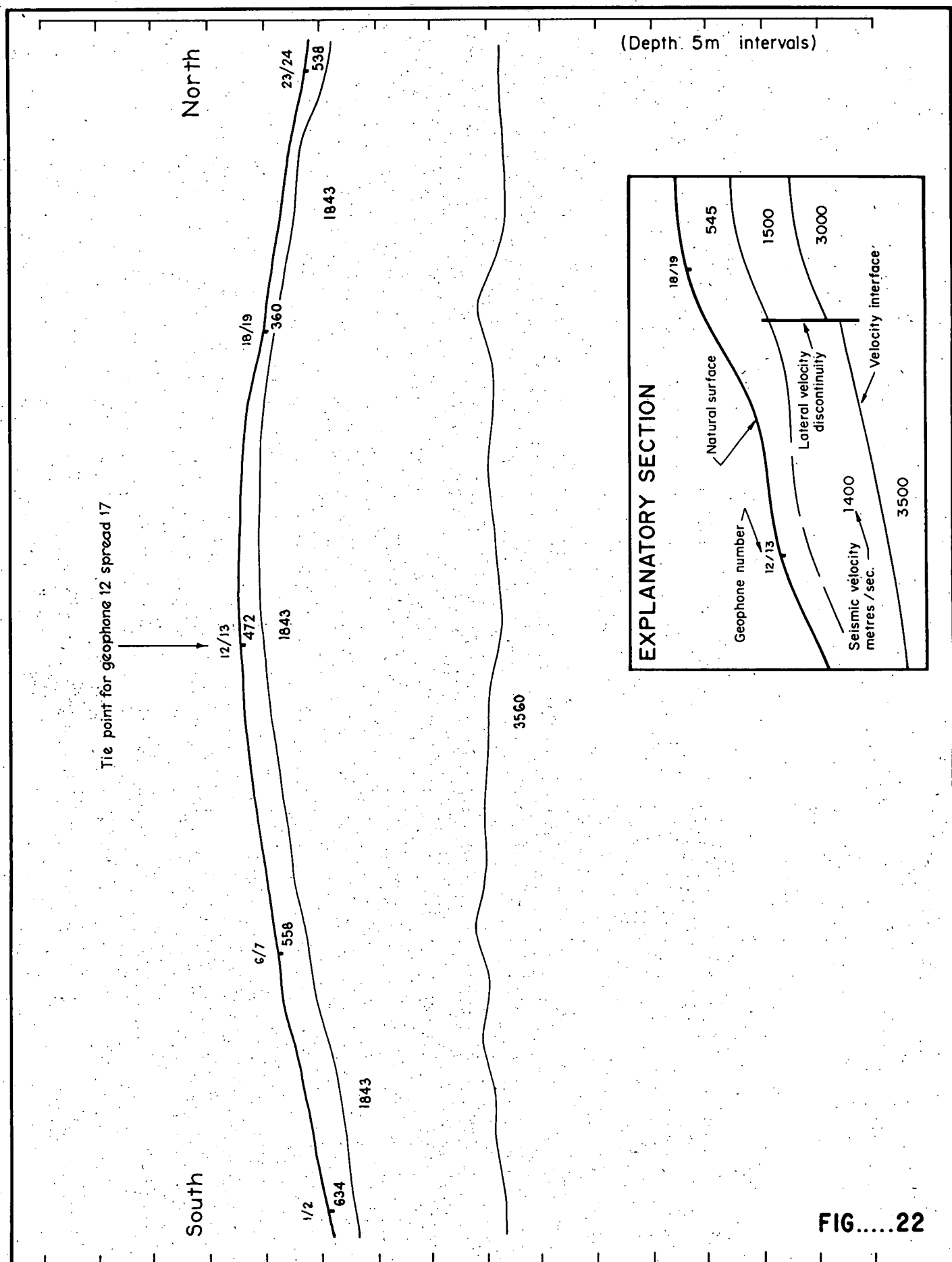

FIG.....22

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA		COMPILED P. Hough	C.D.O. 21·7·87 DATE
SOUTH EASTERN FREEWAY SEISMIC STUDY GLEN OSMOND – CRAFERS SECTION SITE 23 SPREAD 16		DRAWN A.F.	SCALE 1:500
		DATE 9-7-87	PLAN NUMBER S 19378
		CHECKED	

4422

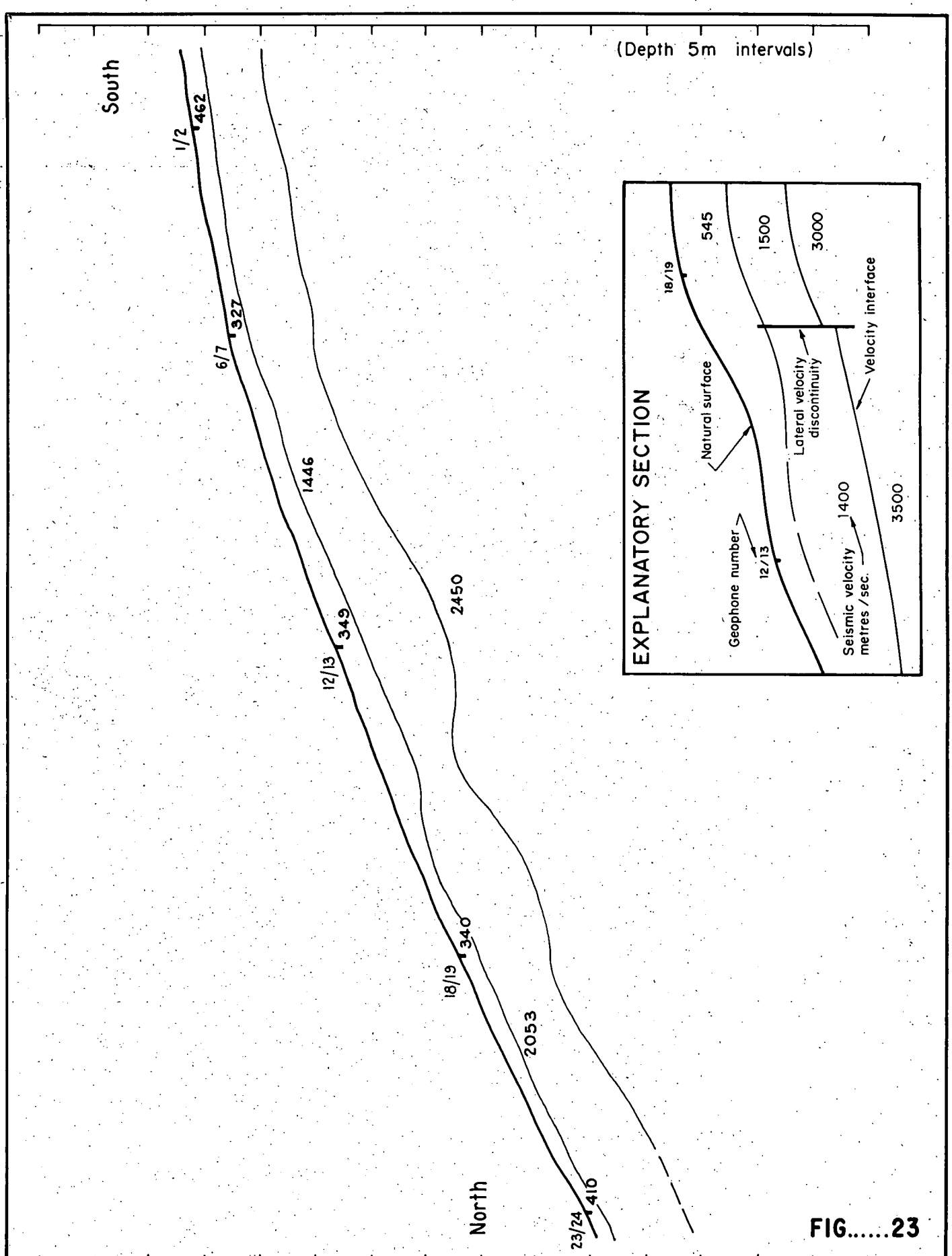

FIG.....23

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 24 SPREAD 18

COMPILED P. Hough	C.D.O. 21·7·87 DATE
DRAWN A.F.	SCALE 1:500
DATE 9-7-87	PLAN NUMBER S 19379
CHECKED	

4422

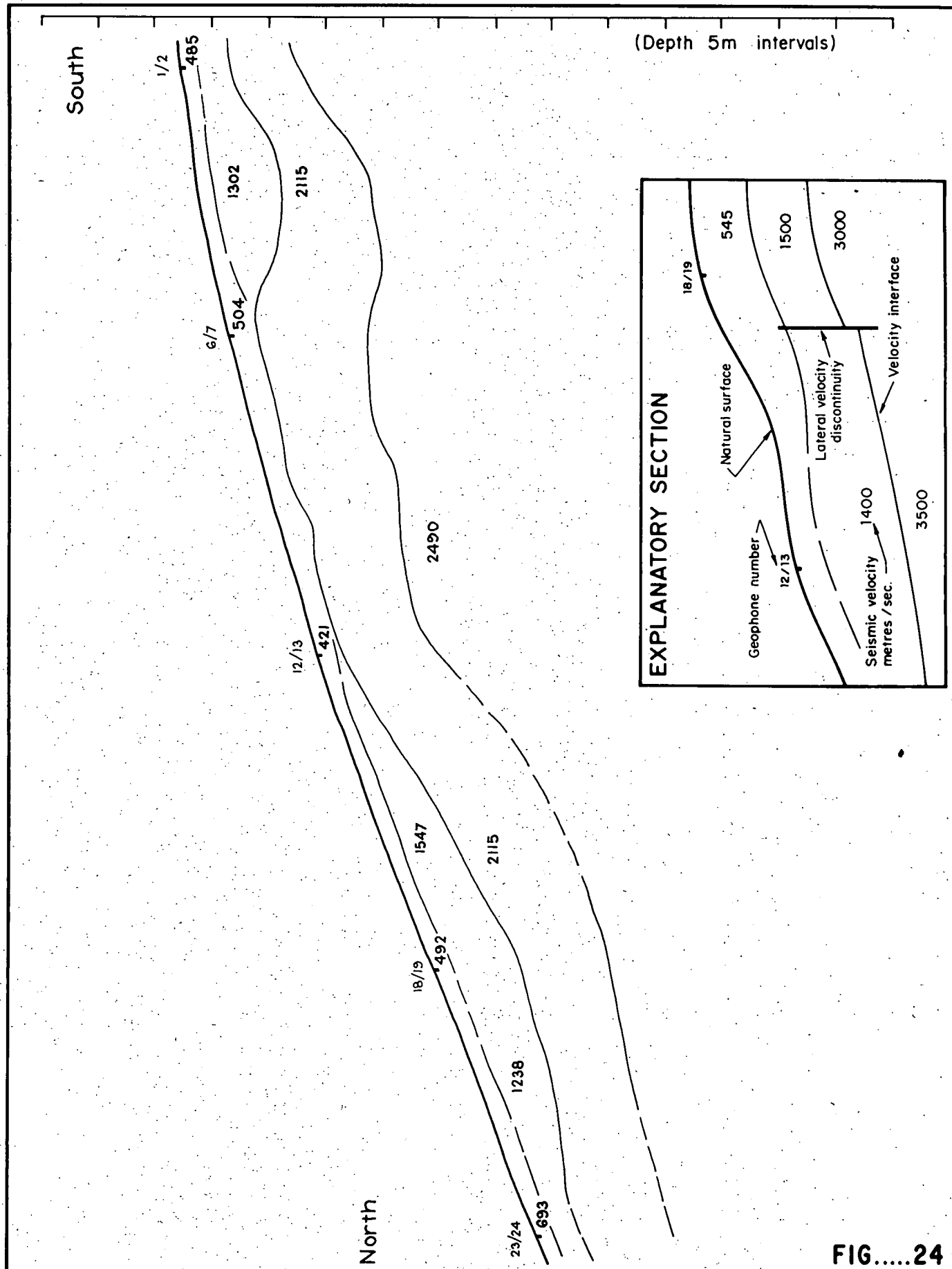

FIG.....24

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

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C.D.O. 21·7·87 DATE

DRAWN A.F.

SCALE 1:500

DATE 9-7-87

CHECKED

PLAN NUMBER S 19380

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 25 SPREAD 19

4427

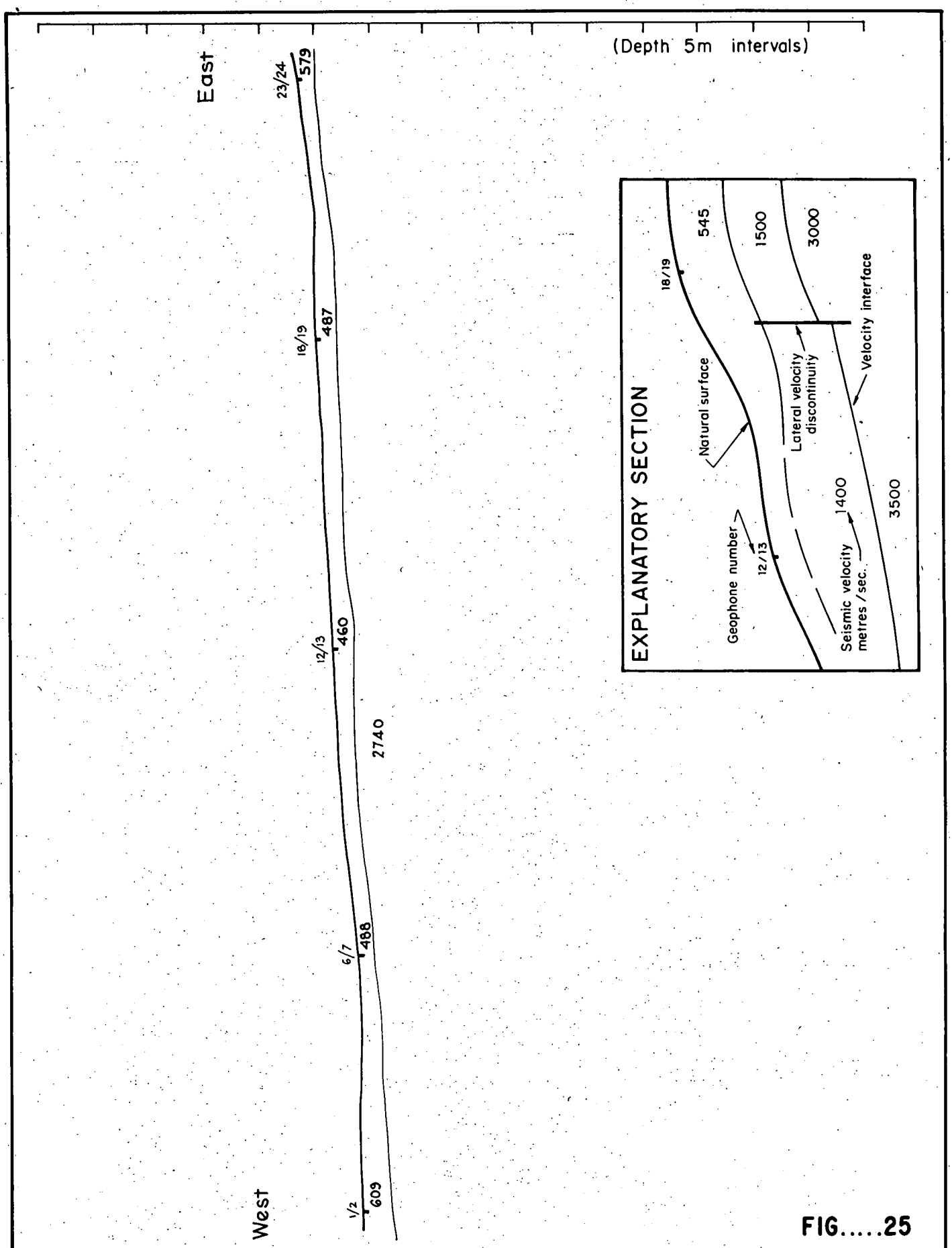

FIG.....25

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

COMPILED P. Hough

C.D.O. 21·7·87 DATE

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 26 SPREAD 24

DRAWN A.F.

SCALE 1:500

DATE 9-7-87

CHECKED

PLAN NUMBER
S 19381

4422

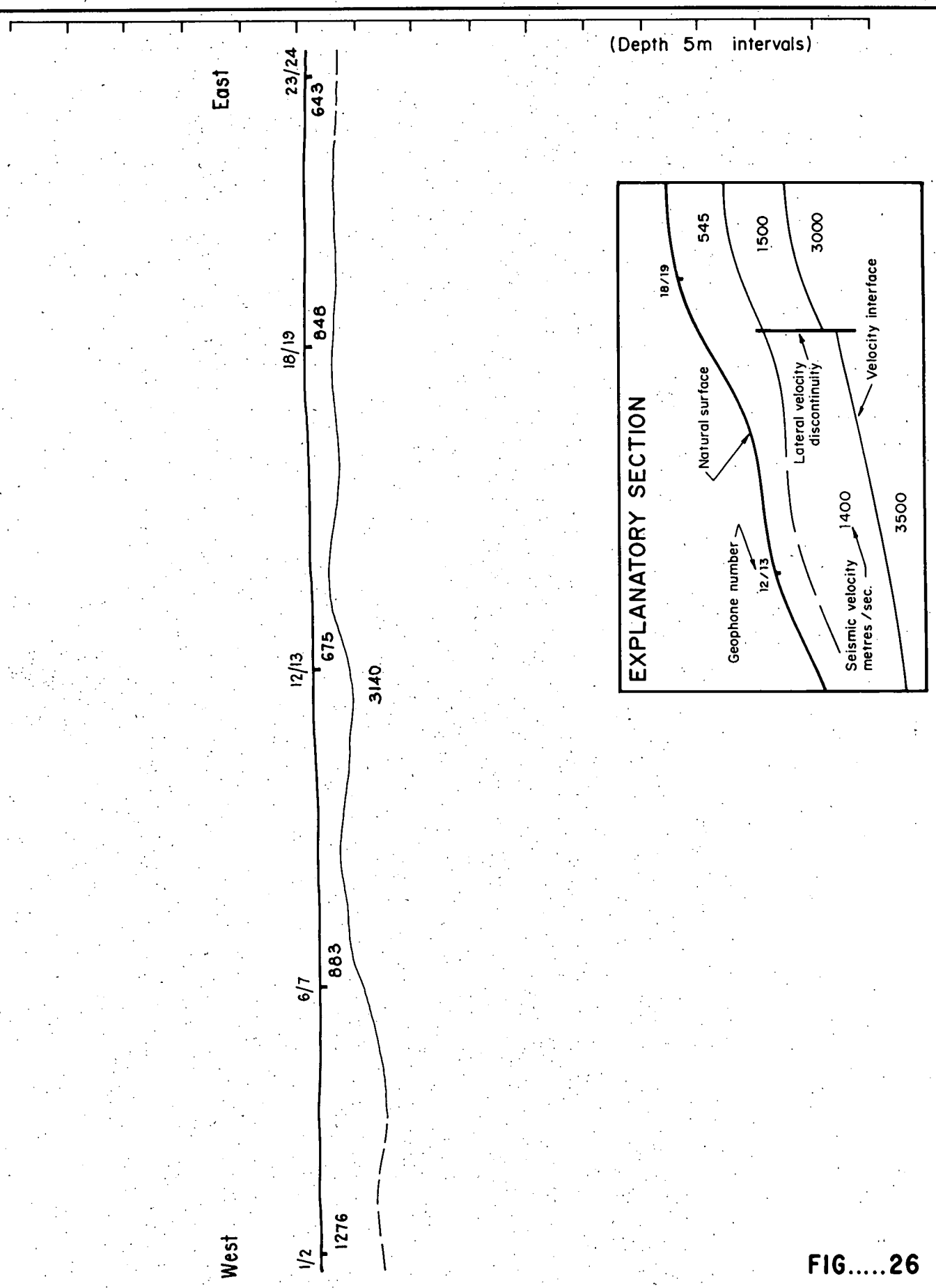

FIG.....26

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

COMPILED P. Hough

C.D.O. 21·7·87 DATE

DRAWN A.F.

DATE 9-7-87

CHECKED

SCALE 1:500

PLAN NUMBER S 19382

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 27 SPREAD 20

4422

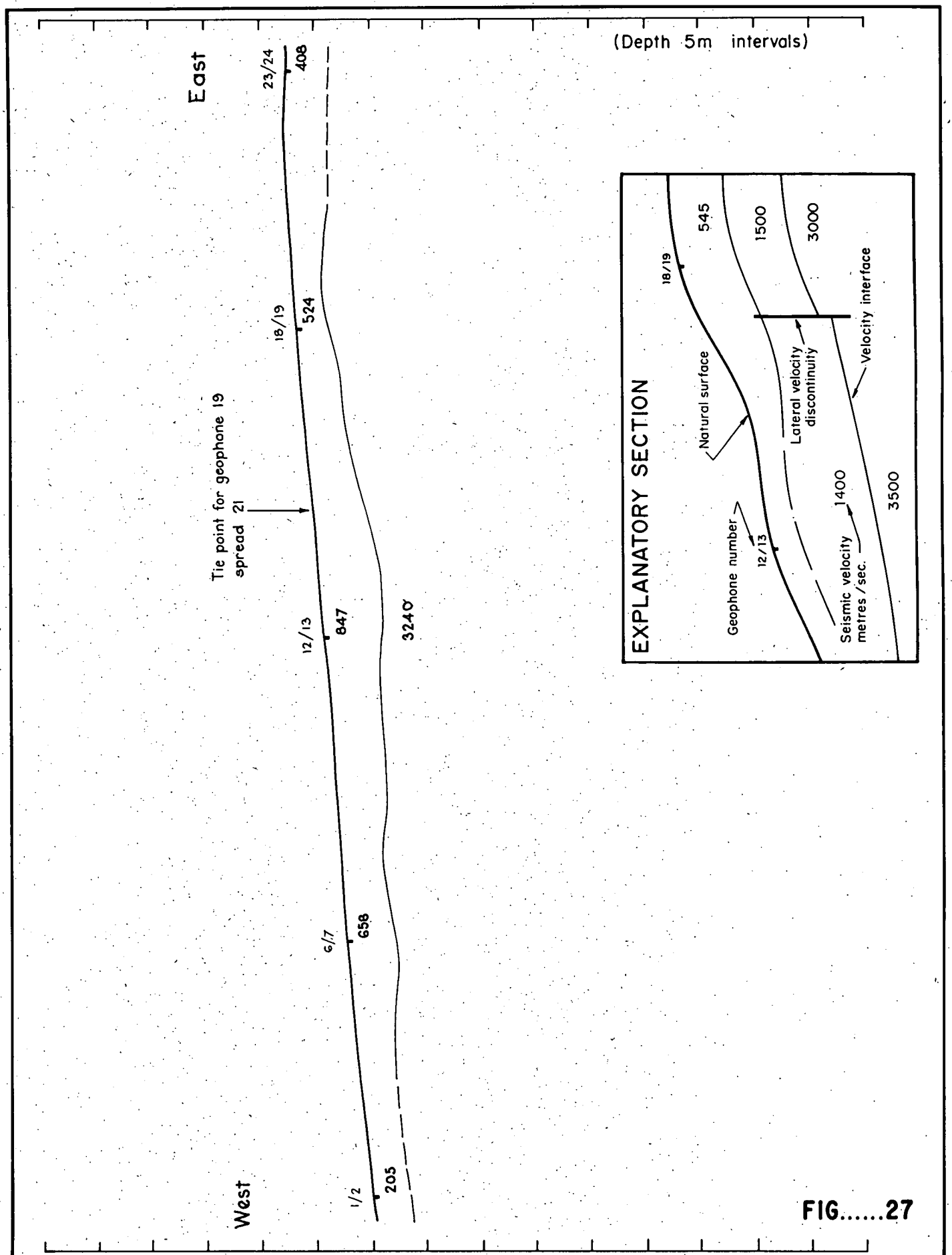

FIG.....27

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 28 SPREAD 22

COMPILED P. Hough	C.D.O. 21·7·87 DATE
DRAWN A.F.	SCALE 1:500
DATE 9-7-87	PLAN NUMBER S19383
CHECKED	

4422

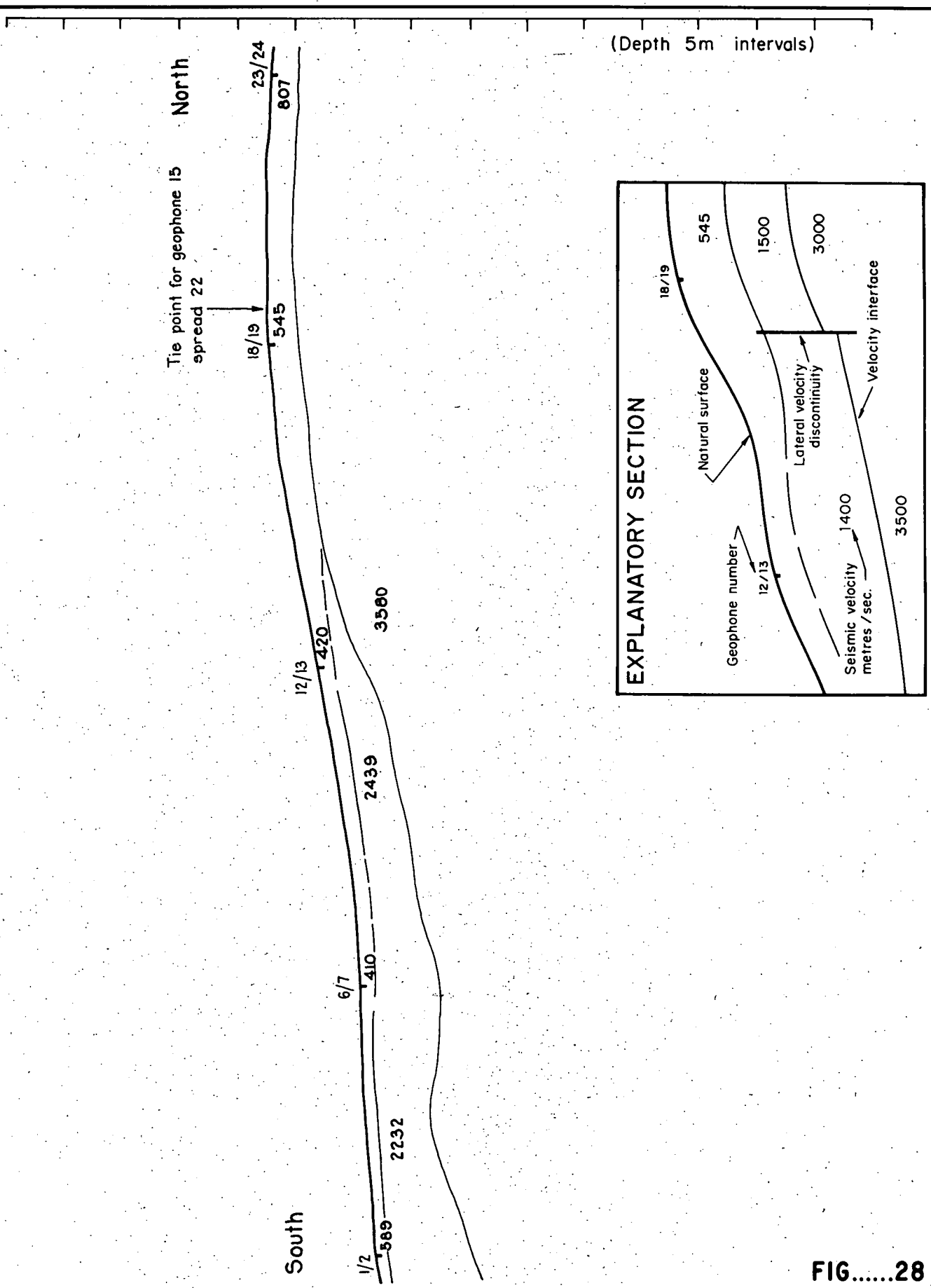

FIG.....28

DEPARTMENT OF MINES AND ENERGY SOUTH AUSTRALIA	COMPILED P. Hough	C.D.O. 21·7·87 DATE
SOUTH EASTERN FREEWAY SEISMIC STUDY GLEN OSMOND – CRAFERS SECTION SITE 29 SPREAD 21	DRAWN A.F.	SCALE 1:500
	DATE 9-7-87	PLAN NUMBER S 19384
	CHECKED	

4422

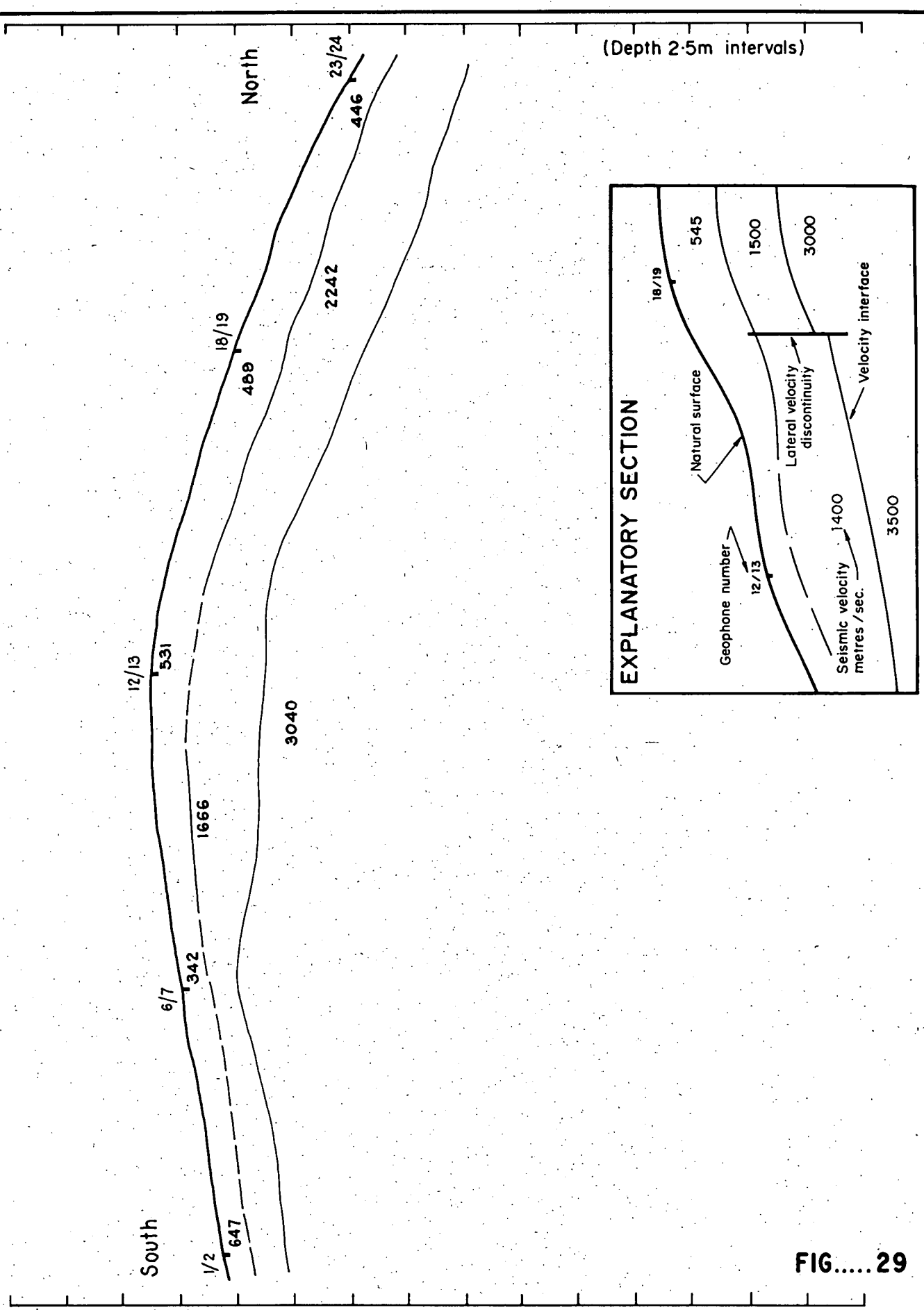

FIG.....29

DEPARTMENT OF MINES AND ENERGY
SOUTH AUSTRALIA

COMPILED P. Hough

C.D.O. 21·7·87 DATE

DRAWN A.F.

SCALE 1:500

DATE 9-7-87

CHECKED

PLAN NUMBER S19385

SOUTH EASTERN FREEWAY SEISMIC STUDY
GLEN OSMOND – CRAFERS SECTION
SITE 30 SPREAD 23

4422