Natural Environment Research Council

Institute of Geological Sciences

Mineral Reconnaissance Programme Report

A report prepared for the Department of Industry

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No. 34

Results of a gravity survey of the south-west margin of Dartmoor, Devon

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Results of a gravity survey of the south-west margin of Dartmoor, Devon

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SUMMARY

A gravity survey (station density 4-6 per km^2) of the south-western margin of Dartmoor, including the Hemerdon stockwork, was interpreted using previously developed computer techniques, with some refinements, to indicate the depth to buried granite. The results showed (i) that the Hemerdon Ball granite is an isolated block and does not extend to depth, and (ii) that no vertically-continuous shallow granite occurs at any distance from the known outcrop. Various computer-graphics presentations of the data are given.

INTRODUCTION

Reports Nos. 1 and 11 in this series (Beer, Burley and Tombs, 1975; Tombs, 1977) described the application of gravity survey methods to the search for shallow concealed granite in three areas of Cornwall. This report describes the results of a similar survey carried out during August, 1977, around the south-west margin of Dartmoor, Devon (Fig. 1). The area was chosen to include the Hemerdon tin-tungsten stockwork (SX 570 580). Existing regional gravity cover showed no anomaly attributable to this granite spur: it was thought that this was a consequence of the coarse station spacing and that a more detailed survey not only would confirm the presence of such an anomaly and permit an interpretation to be made of the subsurface form of the granite, but might also reveal concealed similar structures, of possible mineralisation potential, in the area.

The opportunity has been taken to develop further the computer processing of gravity data. Whilst no fundamental changes have been made to the automatic procedure for obtaining an apparent depth to granite - this is fully described in Report No. 11 - use has been made of the SACM (surface approximations and contour mapping) package to automate fully the process of digitising, plotting and contouring of all data.

FIELDWORK

Gravity observations were made during the period 2-19 August, 1977. Readings were made using La Coste and Romberg meter serial No. 280 at conveniently spaced bench marks and spot heights, normally on roads or tracks but with a few foot traverses to reach higher ground around the edges of the moor. A station density of 4-6 per km^2 was aimed at but the distribution of suitable points necessitated a reduced spacing in some areas. The immediate vicinity of the large and deep Lee Moor china clay excavations was avoided as accurate terrain corrections would be difficult to derive. Station readings were referred to a base at the accommodation address, which in turn was referred to Liskeard FBM. A total of 530 stations was occupied, of which 11 were later rejected as being erroneous. After incorporating the existing regional stations, 690 stations in all were used in the interpretation: their distribution is shown in Fig. 2 although some used to control peripheral values are outside the map.

DATA REDUCTION

After correction of the gravity meter readings for instrumental drift and earth tides, observed gravity values were computed consistent with the national network (NGRN73 - Masson Smith and others, 1974). Bouguer anomalies were then derived by subtraction of the 1967 International Gravity Formula and application of the whole-topography correction developed by the Applied Geophysics Unit, which allows for the earth's curvature. For validation and archiving of data a density of 2.70 g cm^{-3} was used, but for the automatic interpretation procedure the density should be that of granite. (This is because the residual anomalies are finally expressed as departures from the field which would exist if the subsurface rock were granite everywhere within the area considered.) The selected value, 2.65 g cm^{-3}, is probably reasonable for the Dartmoor granite (Bott and others, 1958).

INTERPRETATION

Interpretation was based on the procedure described in the section entitled "The Gravity Surveys" in Tombs (1977). The following account, including discussion of minor differences and refinements in technique, assumes familiarity with that section.

Small changes were made to parts of the existing batholith model to improve the fit between the computed anomaly derived from it and the actual Bouguer anomaly. This comparison was made on a 2 km grid within a square of side 30 km centred on the survey area. Observed Bouguer anomalies at grid intersection points were calculated using the numerical approximation technique in SACM. The final RMS error was 2.27 mGal compared with a total range of actual values of 44 mGal; this was considered acceptable to define the regional field. Subsequent computations over the rectangular area shown in the figures were made at points on a surface representing topography which was derived, using SACM, from the elevations of the gravity stations. Such a surface, whilst a rather poor approximation to actual topography because of the non-random distribution of gravity stations, requires no labour to define it and is probably adequate in the present area where the topography is in general moderate. Computations were made over a 0.25 km grid with 61 points in the X direction (=Easting) and 73 in the Y direction (=Northing). A killas-to-granite density contrast of 0.15 g cm^{-3}, which was satisfactory in the polygon model and consistent with the generalised geology, was used for the iterative program. After 8 iterations the output was taken as final: the RMS error had decreased to 1.14 mGal and the rate of further decrease was very slow. This required the long execution time of 59 minutes on the Rutherford IBM 360/195 computer, but a grid of this size was probably necessary to define the outward slope of the granite in sufficient detail

Figs. 2-5, all produced on the FR80 plotter by SACM, show respectively the observed field and the positions of gravity stations; the regional field; the residual field; and the computed depths to granite. Fig. 2 gives an indication of the station density: the SW and extreme NW and NE parts of the map were covered only by regional stations. Certain minor closures not enclosing stations are produced by SACM in an attempt to avoid sudden changes of slope; one or two doubtful stations remain.

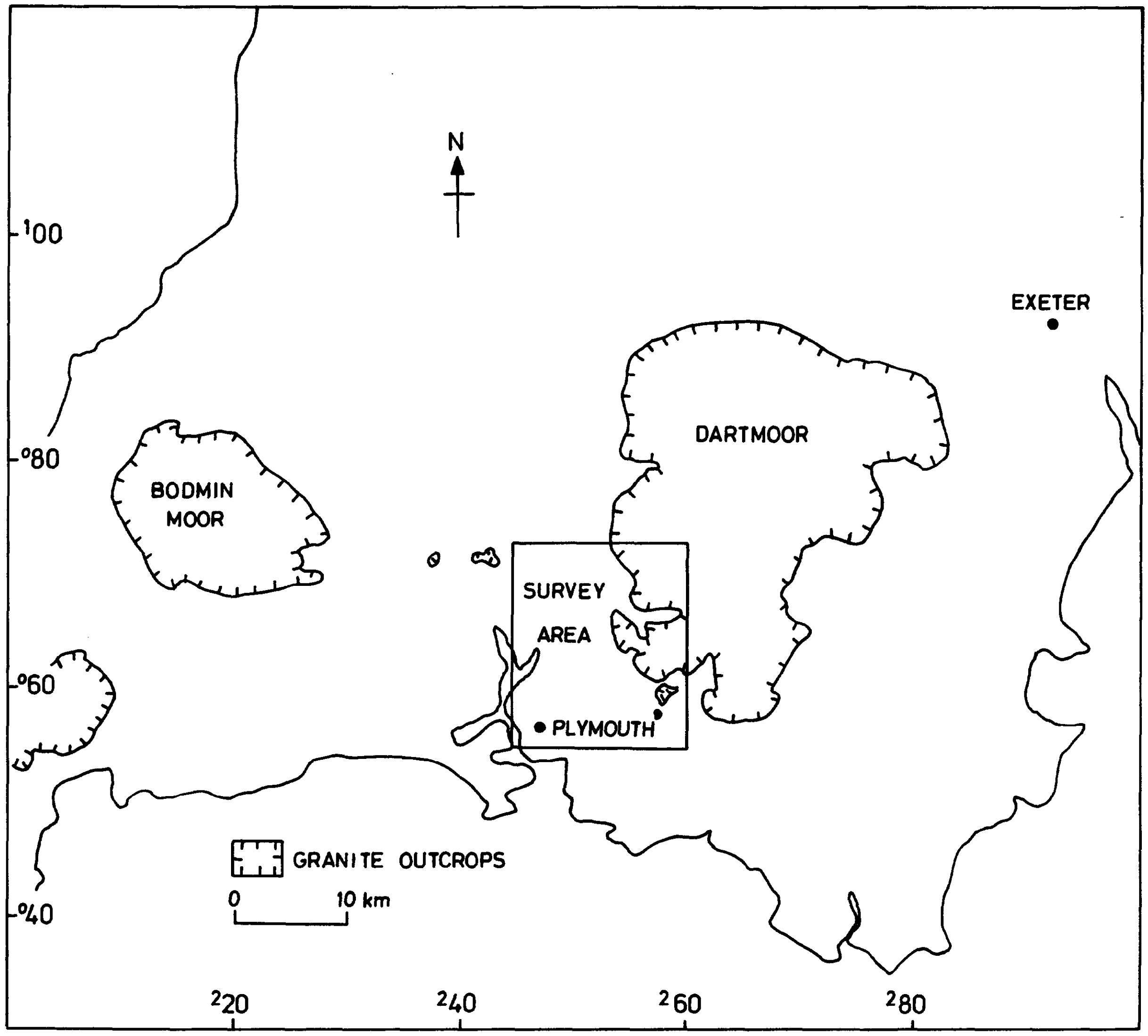


FIG. 1. LOCATION MAP

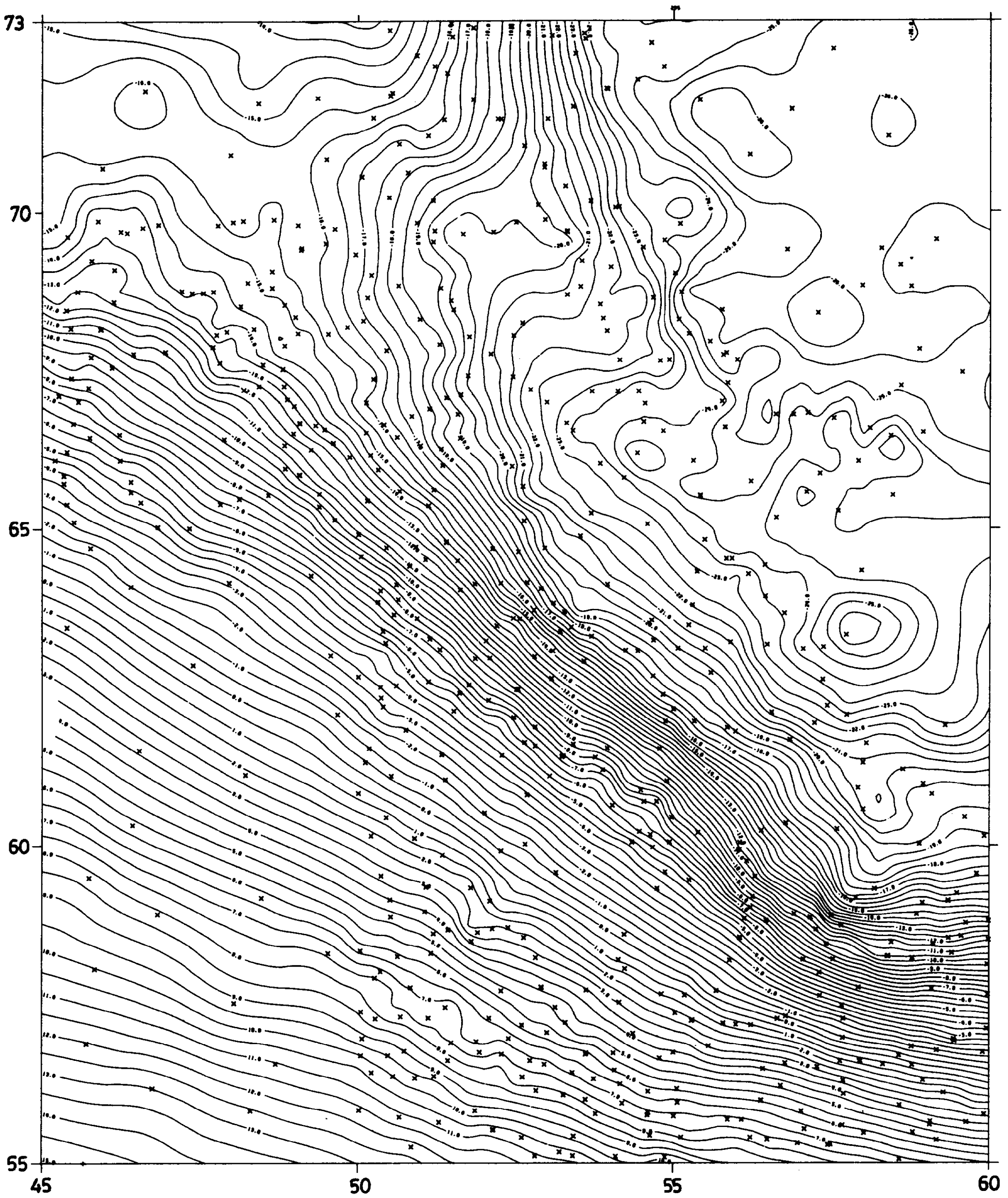


FIG. 2. BOUGUER ANOMALY MAP AND STATION POSITIONS
DENSITY OF REDUCTION 2·65 g/cm^3

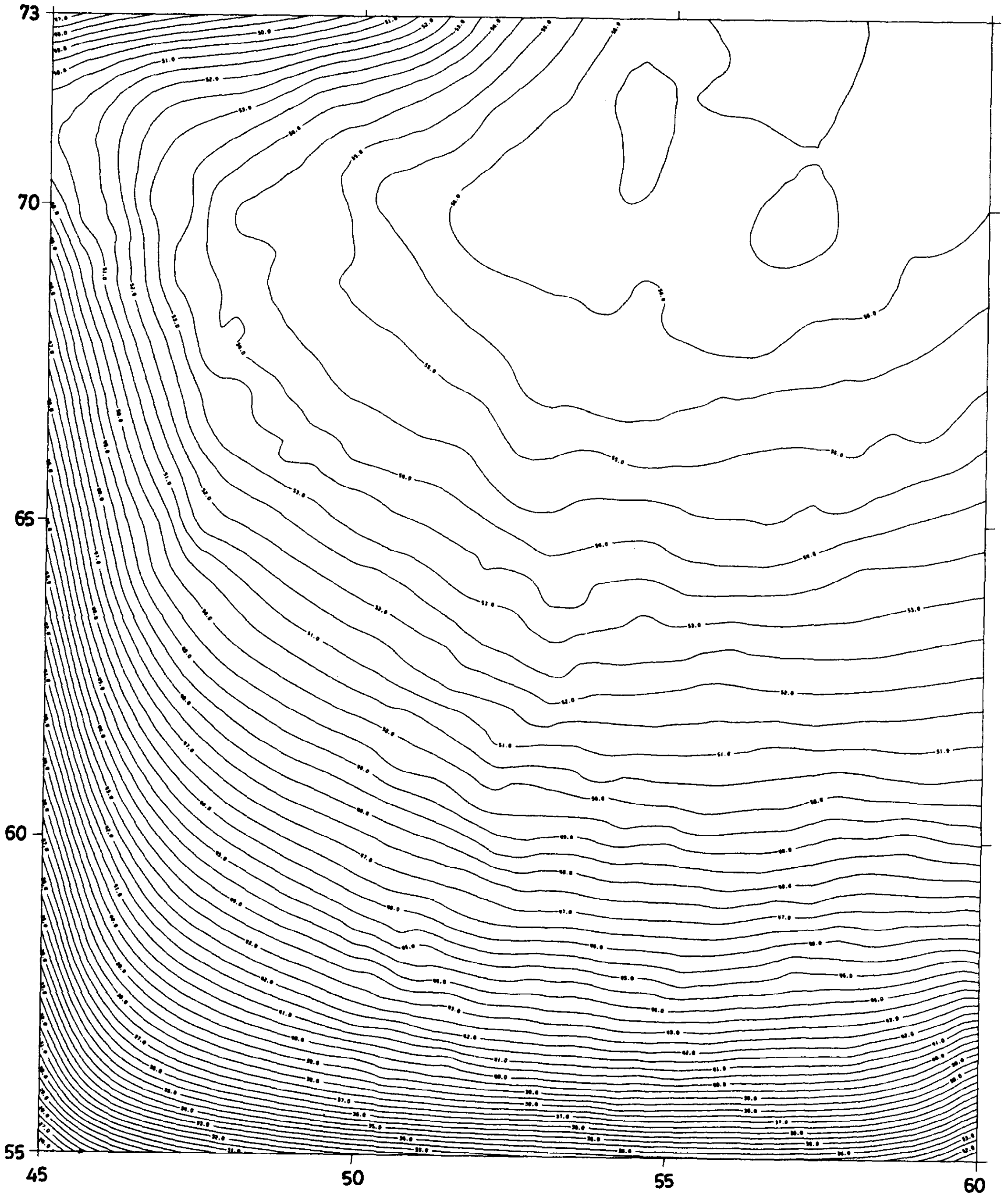


FIG.3. REGIONAL FIELD IN MGAL

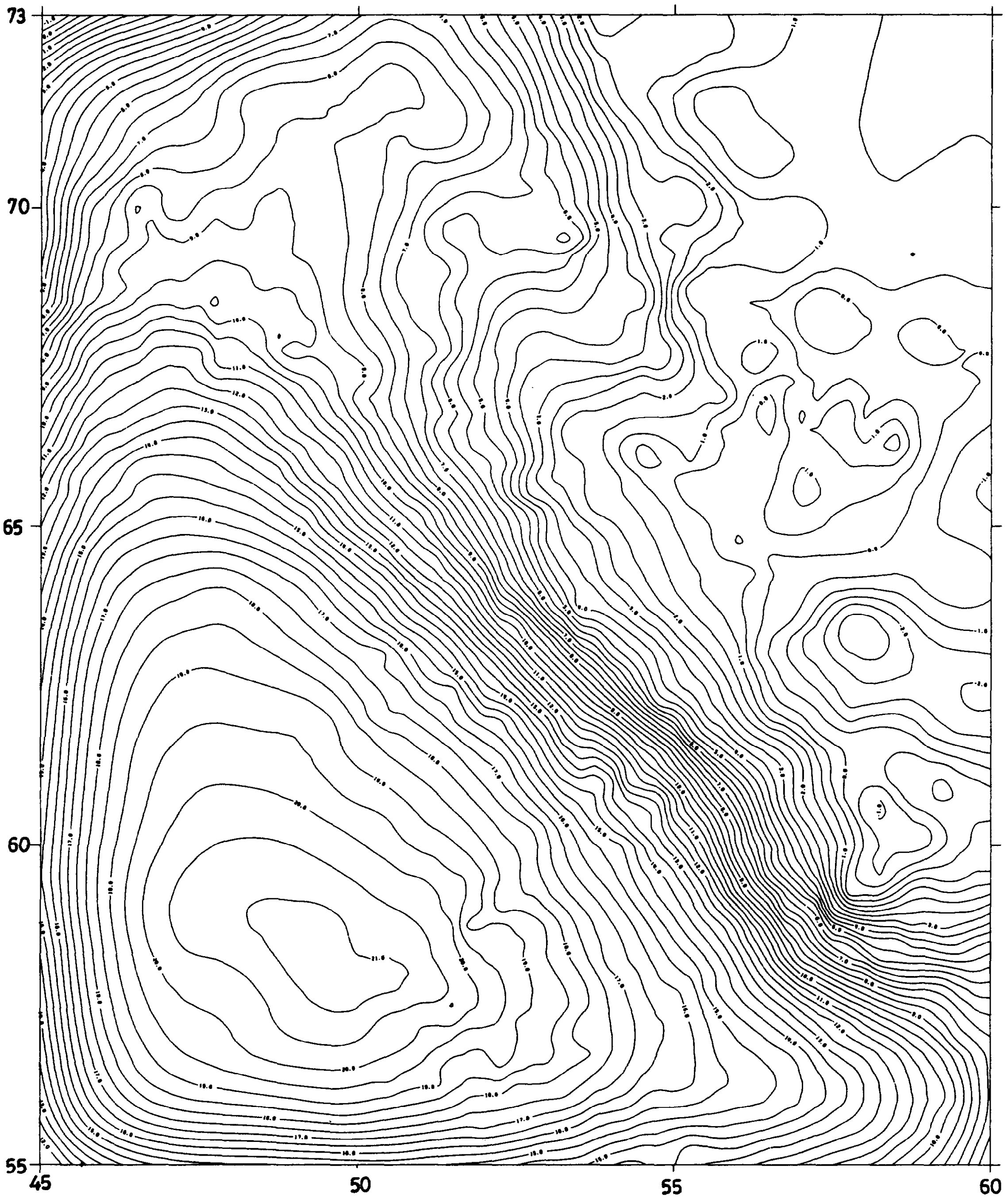


FIG. 4. RESIDUAL FIELD IN MGAL

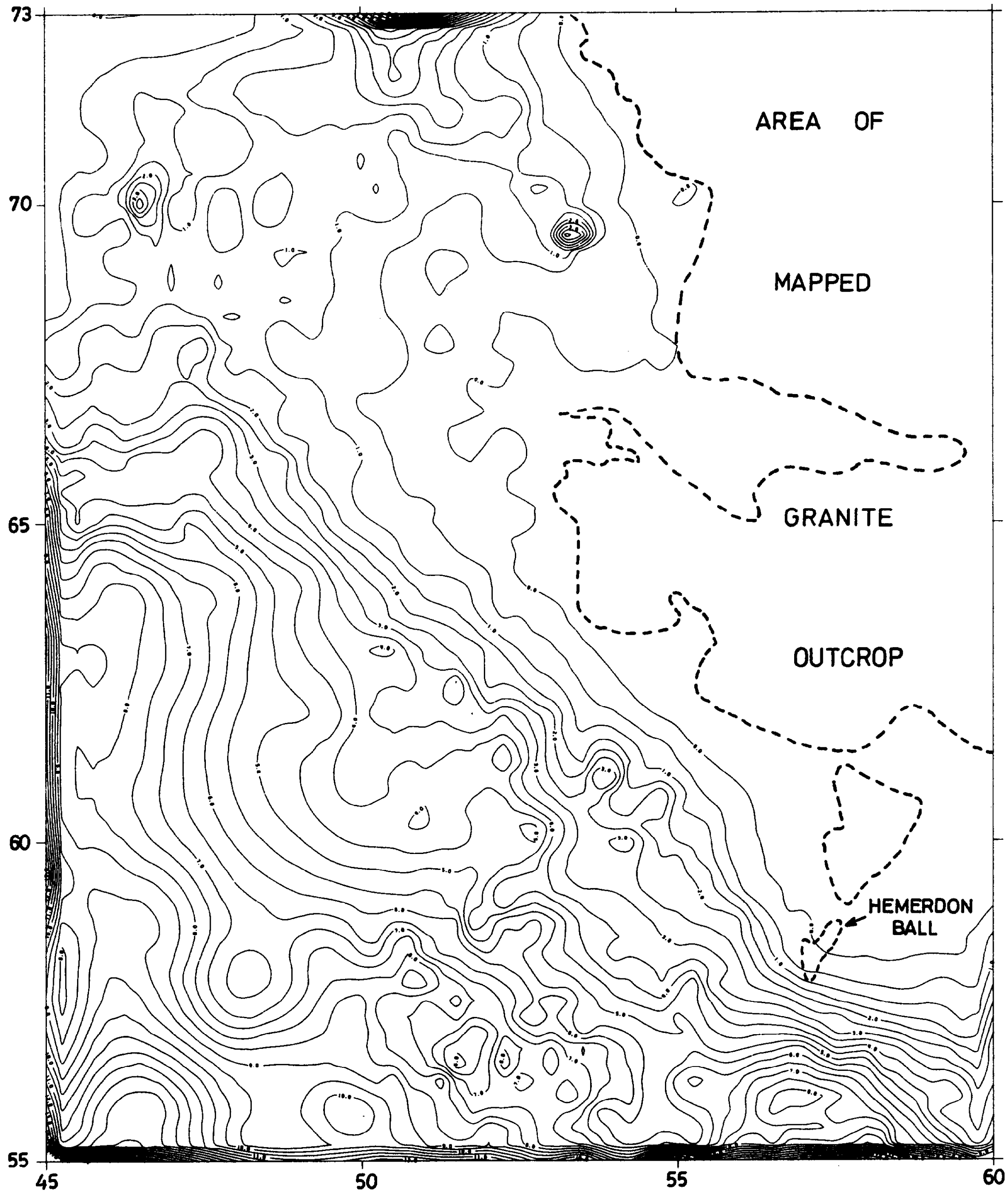


FIG. 5. INTERPRETED DEPTH TO GRANITE BELOW SEA LEVEL IN KM

The values in Fig. 3 should be negated and 30 mGal added to make them comparable with Fig. 2. The short-wavelength features on Fig. 3 are due to inaccuracies in the numerical integration part of the program which computes the gravitational effect of a body defined by polygonal contours. The curvature of the contours near the edges, of both Fig. 3 and Fig. 4, shows how the modified batholith model attempts to isolate the residual field due entirely to killas within the rectangular area. Fig. 5 shows how remaining edge effects seem to be restricted to one peripheral grid spacing only. The depth map looks cluttered because of the magnifying effect of the iterative program on 'noise' in the observed field; in particular the localised deep trough near (SX 53 70) is probably unreal and a consequence of one doubtful station. The limits of granite outcrop have been added; by comparison with this, the zero granite contour, representing granite at sea level, looks reasonable over most of its length.

Figs. 6 and 7 are a sequence of perspective views of the granite surface, without vertical exaggeration, viewed from the southern and western sides. (One row of values, with severe edge effects, has been removed from the S, W and N edges). They give a better impression than the contour map of the way the granite falls away steeply from its outcrop except in the north. (The actual slopes, calculated from Fig. 5, average 50° - 70°).

The mesh size of 0.25 km means that sharp features such as faults cannot be treated accurately; nevertheless the perspective drawings show certain apparent lineations, not obvious on the contour map which can tentatively be recognised as faults. These have been indicated.

In considering which features of the granite form are genuine and which may be due to "noise", density variations or an inaccurate regional field, it is helpful to consider whether a significant change in the feature would cause a significant change (say > 1 mGal) in observed gravity at the surface. Qualitative consideration along these lines suggests that the near-surface outward slope is probably broadly correct; the medium-wavelength undulations in the SW corner are rather doubtful; and the short wavelength features, which do not correlate between lines on the perspective drawings, are probably unreal.

Figs. 8 and 9 are true-perspective representations of the current batholith model, with a crude coastline superimposed.

Geological implications

The gravity data after interpretation give little indication of the Hemerdon Ball granite spur, suggesting that it is not continuous with the batholith, but rather an isolated body of limited depth extent (see Appendix). Partial confirmation of this has been provided by the drilling results of the mining company which is investigating the prospect. They have also demonstrated very local gravity anomalies of up to 0.5 mGal (of too small an extent to be resolved on the present survey), which may be due at least in part to local kaolinisation (F. P. Fritz, pers. comm.). This conflicts with the historical notion of Hemerdon Ball being a "cupola" (e.g. Dines, 1956, p. 685) and of course means that if buried bodies similar to Hemerdon exist they may be undetectable to gravity survey at this station spacing. There is in fact no indication of shallow granite at any distance from the known outcrop; even the ridge extending north-westwards towards Kit Hill appears to be at about 1 km depth. The embayment at Ringmoor Down (SX 56 66) has a thin killas cover, with granite mostly above sea level.

CONCLUSIONS

The existence of buried shallow granite bodies similar to Hemerdon Ball has been neither proved nor disproved, but it would appear that gravity surveys designed to detect such bodies should be confined to areas very close to the granite margin and should employ an average density much greater than that of the present survey. The Hemerdon body itself appears to be geologically anomalous in that it is not connected at depth with the main granite body. One possibility may be that it has been preserved by downward block-faulting from a level originally higher than the present erosion level; in this case the preservation of its associated minerals must be the exception rather than the rule.

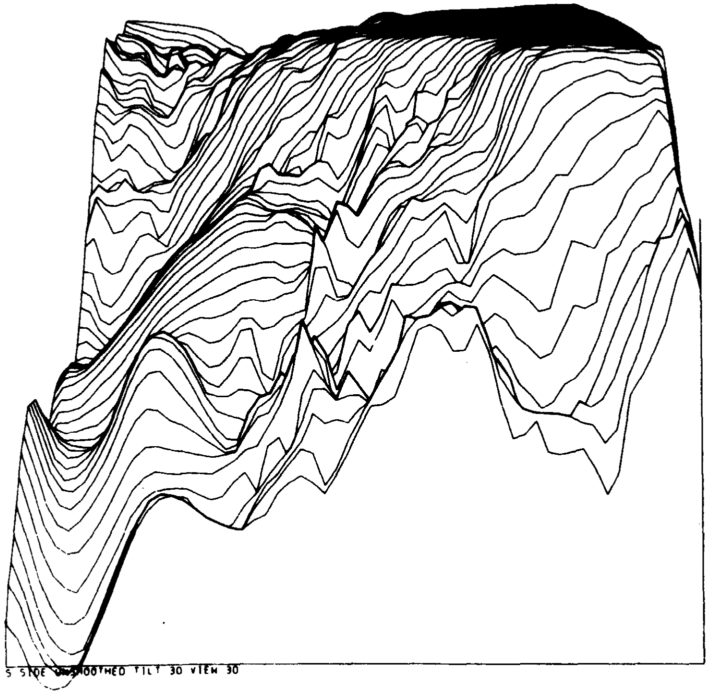
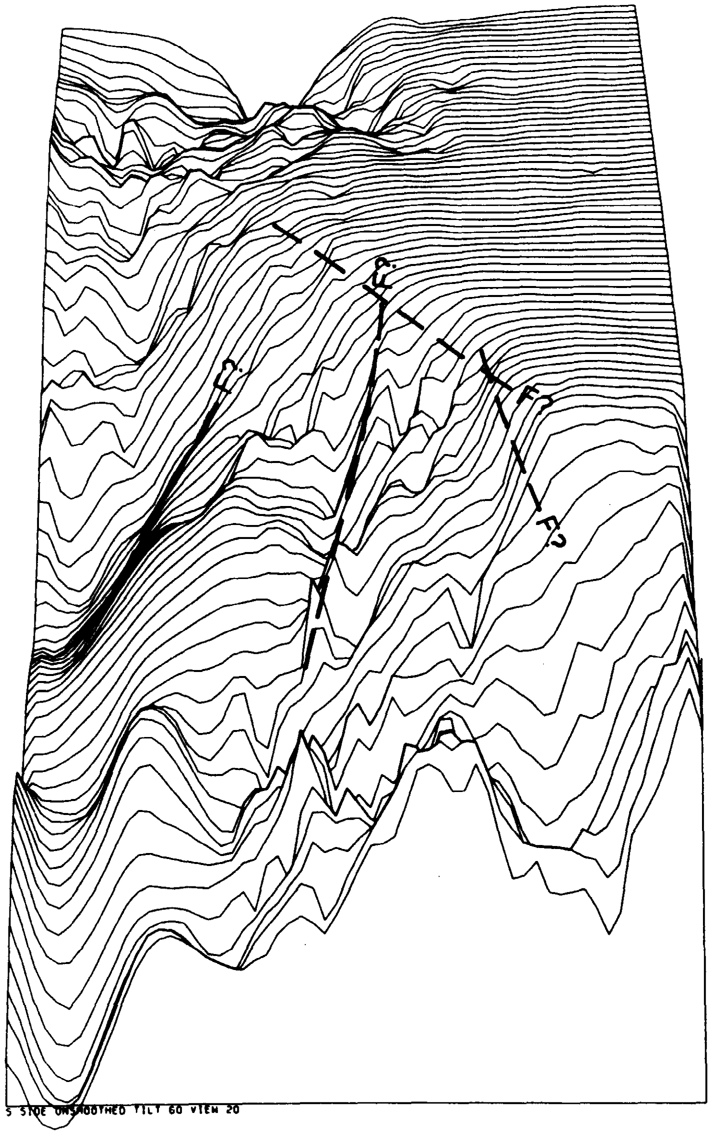


FIG. 6. PERSPECTIVE VIEWS OF GRANITE SURFACE, VIEWED FROM THE SOUTH

THE RIGHT-HAND VIEW IS FROM A HIGHER VIEWING POSITION



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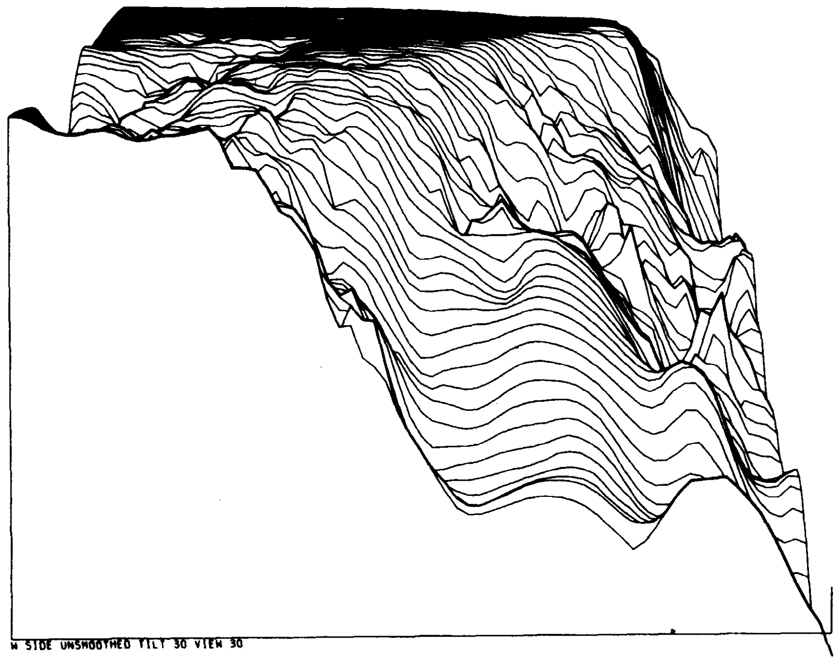

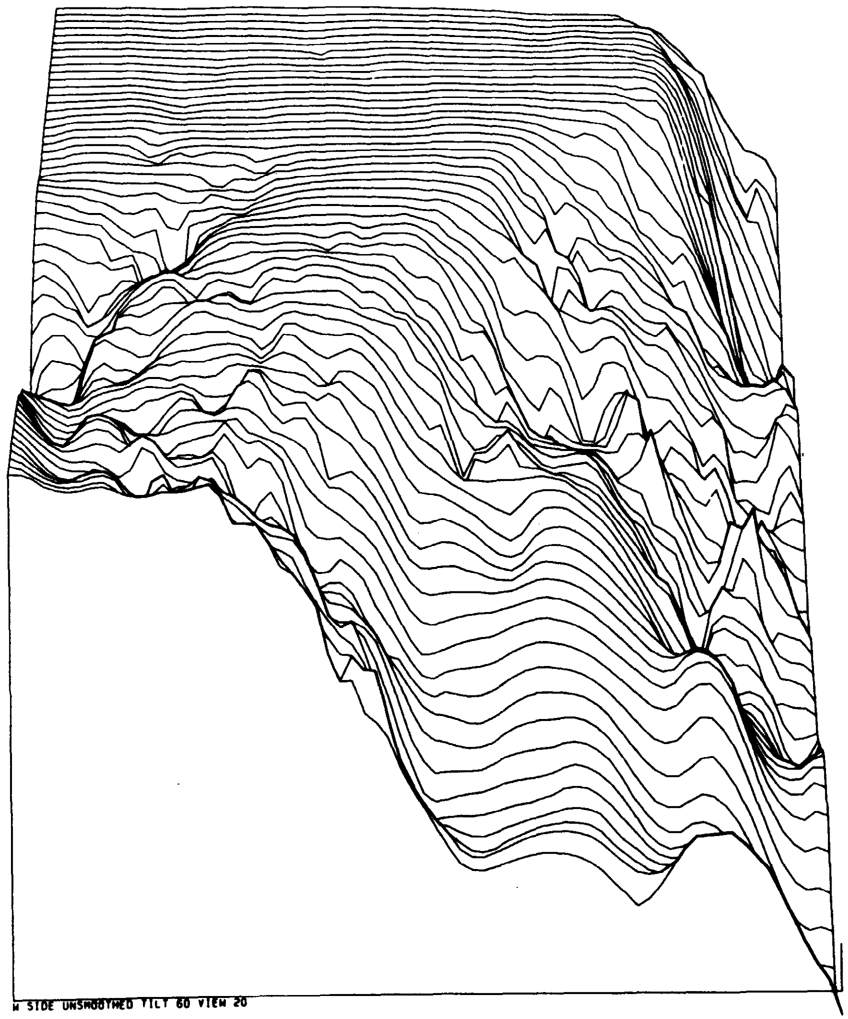

FIG. 7. PERSPECTIVE VIEWS OF GRANITE SURFACE, VIEWED FROM THE WEST

THE RIGHT HAND VIEW IS FROM A HIGHER VIEWING POSITION

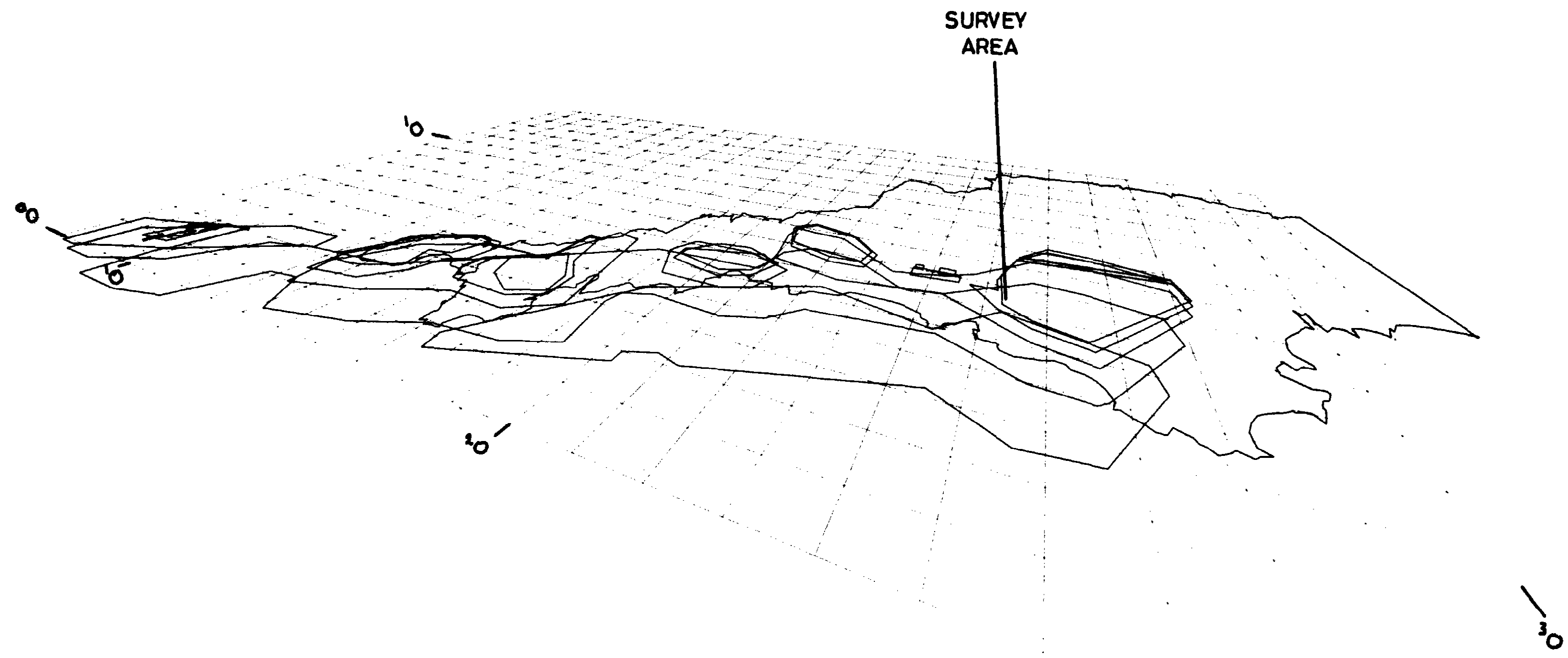

FIG. 8. PERSPECTIVE VIEW OF THE BATHOLITH MODEL, FROM THE SOUTH

THE DEPTHS OF THE POLYGONAL SURFACES ARE 0·1, 1, 3, 9, 20KM BELOW SEA LEVEL

THE GRID IS BRITISH NATIONAL GRID, 10KM INTERVAL

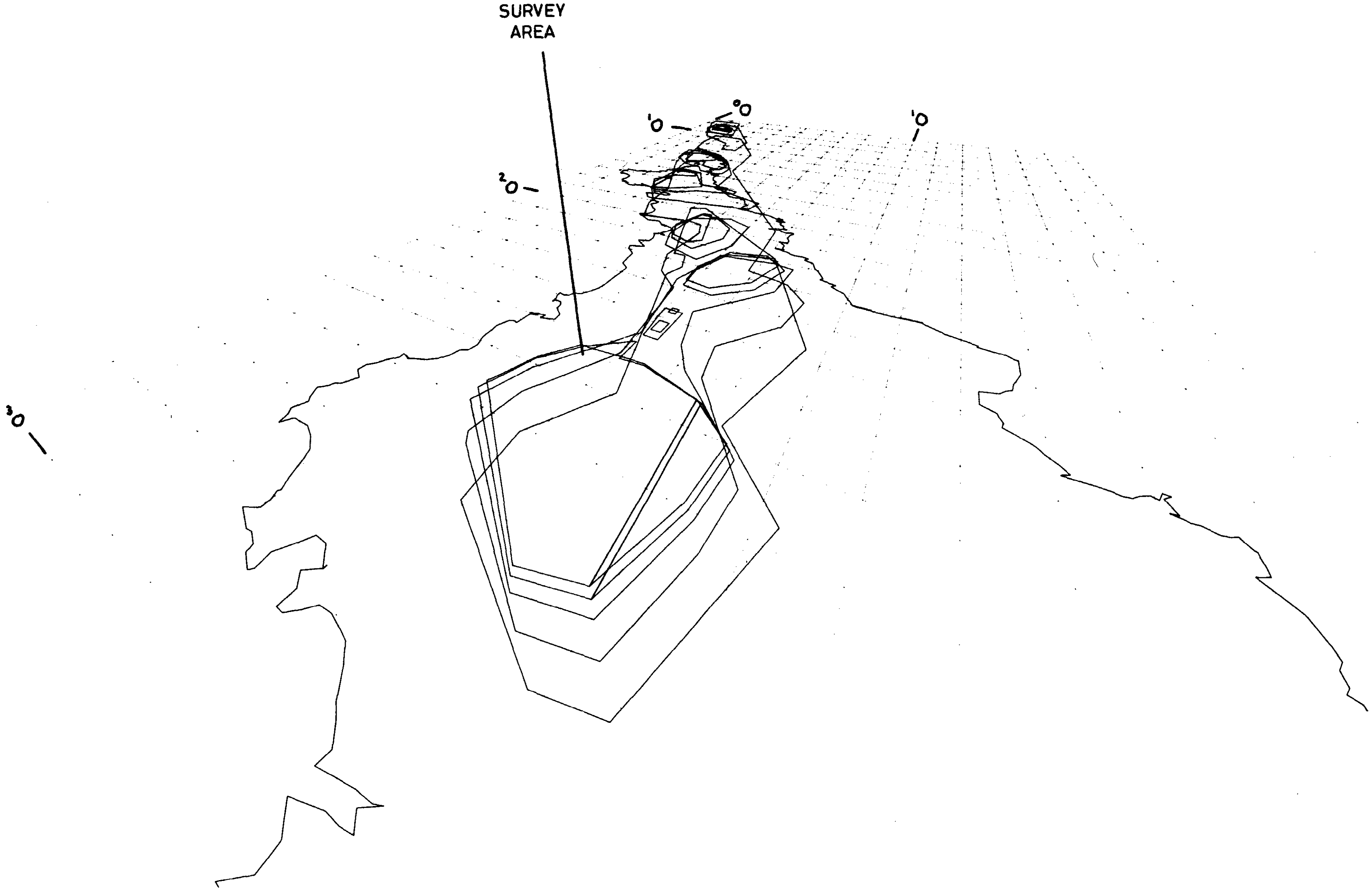

FIG.9. PERSPECTIVE VIEW OF THE BATHOLITH MODEL, FROM THE EAST

THE DEPTHS OF THE POLYGONAL SURFACES ARE 0·1, 1, 3, 9, 20KM BELOW SEA LEVEL

THE GRID IS BRITISH NATIONAL GRID, 10KM INTERVAL

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APPENDIX

The effective resolution of this survey can be illustrated by a semi-quantitative treatment of the type of body which would be detected.

(1) Smallest cupola which would be detected by the present survey.

Examination of the station distribution in Fig. 2 suggests that a cupola would be detected if its residual anomaly were > 0.5 mGal over a circle of radius 0.5 km. A typical shallow cupola may have a local anomaly similar to that of a sphere just touching the surface; in this case the criterion above leads to a minimum detectable radius of ≈ 0.5 km.

(2) Station density needed to detect Hemerdon-type bodies.

Assume the Hemerdon body is 200 m wide, 200 m deep and 1 km long. A reasonable criterion is two gravity stations over the body, each with a residual anomaly > 0.5 mGal. Ignoring end effects the anomaly is > 0.5 mG within ≈ 100 m of the centre line, so we have two stations in 0.2 km^2 or 10 stations per km^2.

(3) Possibility of depth extension of Hemerdon.

If Hemerdon were as in (2) but 20 km deep, a full three-dimensional solution gives an anomaly > 0.5 mGal over an oval area of dimensions $\approx .6 \times 1.2$ km or ≈ 0.6 km^2 area. Requiring two stations within this area implies a density of 3 per km^2 which is exceeded in the Hemerdon area; furthermore granite contacts in fact normally slope outwards and the anomaly would be greater. Therefore the Hemerdon body is certainly vertically confined or narrowing with depth.