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IMPLICATIONS OF THE OCCURRENCE OF LARGE GRAVITY GRADIENTS IN NORTHERN TIMOR

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SUMMARY

Recent gravity measurements in eastern Timor have shown that steep gradients occur in the northern part of the island, and that the maximum Bouguer Anomaly values attained are greater than those on the inner volcanic arc immediately to the north. The observations can be explained only by supposing that the dense source rocks rise very close to the surface, and analogies can be drawn with the large anomalies associated with ophiolitic thrusts in New Guinea and New Caledonia.

The pattern of volcanic activity north of Timor also resembles that of eastern New Guinea, suggesting, again by analogy, that a thrust slice is wedged in the subduction zone south of the inner Banda arc. If correct, this hypothesis provides some support for the concept of Timor as built up of a series of thrust slices resting ultimately on continental basement.

In August 1974 a number of gravity measurements were made in eastern Timor, using a LaCoste Romberg model G geodetic gravity meter. Two traverses were made across the island, along roads running roughly south from Dili and from Baucau, and a number of readings were taken at or near the north coast between these two towns (Figure 1).

Absolute values were obtained by reference to the survey pillar MGT 1956 at Dili Airport, which has been tied to the Australian Government gravity base in Darwin (C h a m e l a u n et al, 1976).

Heights were obtained either from survey pillars, or by direct reference to local sea level or from 1 : 50,000 topographic maps contoured at 25 metre intervals.

Station coordinates were also estimated from these maps, and normal gravities computed using the 1967 international formula.

1. *Bouguer Anomaly Values*

The pattern of low Bouguer Anomaly values and low gradients near the south coast and high values and steep gradients near the north coast reported by other workers (R i t s e m a, 1956; C h a m e l a u n et al, 1976) is apparent in the cross-island traverses.

An additional striking feature is the zone of very steep gradients to the east of Manatuto, where the highest onshore Bouguer Anomalies yet reported from Timor are found. Not only are the three highest values almost 200 milligals greater than the lowest recorded in the south coast region, but they are also 10 – 20 milligals higher than the value obtained at the airstrip on the inner arc island of Atauro to the north.

With the stations read it is not possible to define contours, and hence true maximum gradients in the Manatuto area can only be roughly estimated.

Changes of 30 milligals in distances of 3 km seem probable, and it is also notable that there must be significant departures from the general east-west contour trend.

Steep gravity gradients characterise the outer zone islands of many, if not all, island arcs, and in this respect the Timor gradient may be considered normal.

However, Timor is unusual for such an island in its extremely short distance from the volcanic inner arc, the volcanic island of Atauro lying only about 30 km from its northern coast.

The Timor gradient is thus anomalous in that, because of the absence of a properly developed inter-arc trough, two blocks of thickened crust are in near contact at the gravity anomaly peak.

2. *Comparison with ophiolite belts*

Gravity gradients similar to those across Timor have also been measured in the vicinity of major ophiolitic masses, and several of these have been compared in a discussion of the Papuan Ultramafic Belt (M i l s o m, 1973).

The closest geophysical analogy with Timor is provided by New Caledonia, in that there also only a part of the gradient can be mapped on land and the maximum Bouguer Anomaly values are presumably reached offshore (C r e n n, 1953).

The resemblance between the two islands is heightened by the presence north-east of New Caledonia of a line of smaller islands, on at least one of which intermediate igneous rocks have been found. It is commonly accepted that the New Caledonian anomaly, and also that in Papua, which can be more completely defined by land measurements, is caused by the concealed roots of the exposed ultramafic masses.

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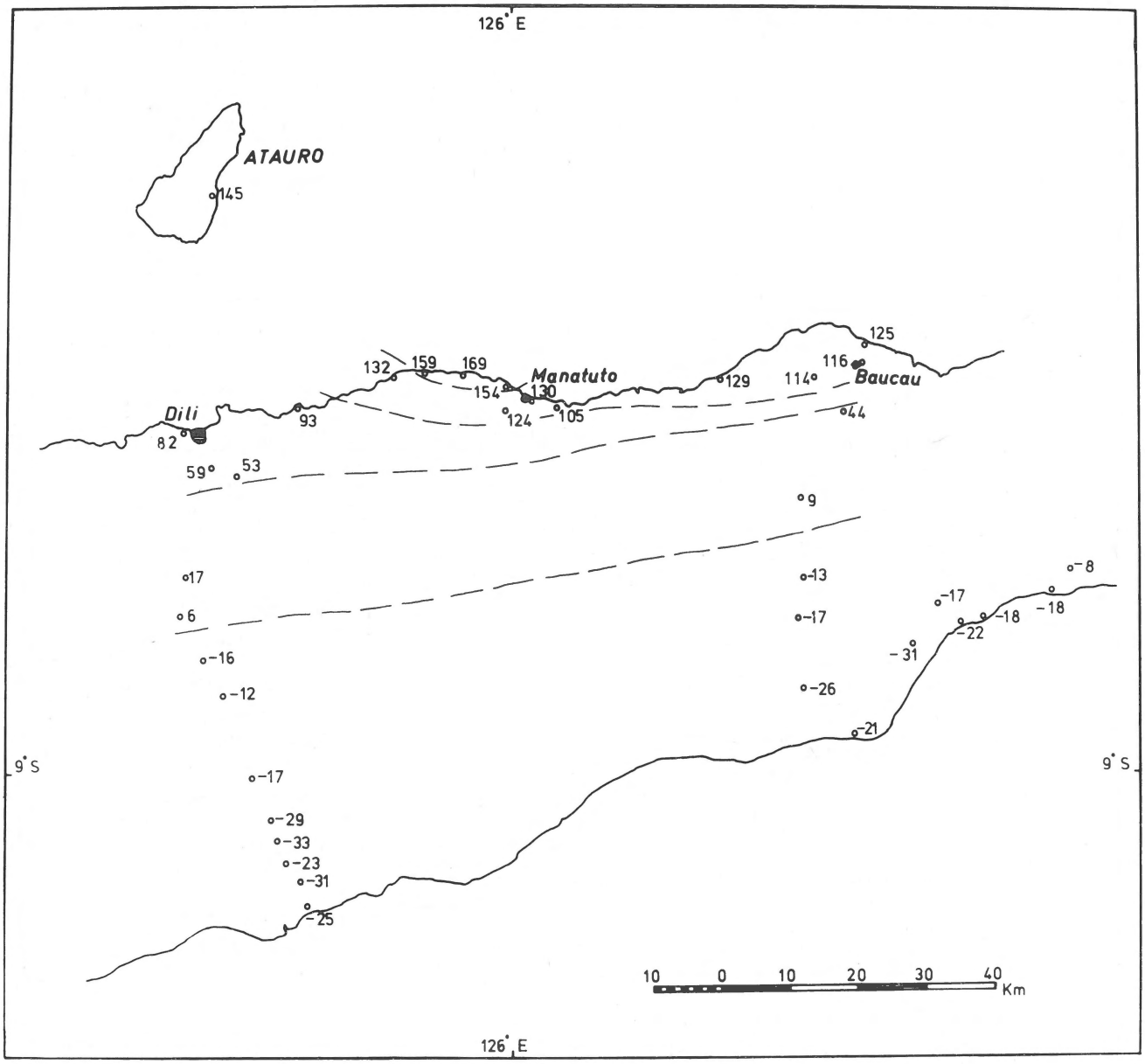

Fig. 1
Simple Bouguer Anomalies, eastern Timor. Reduction density 2.60. Contour trend lines at 50 milligal intervals.

True ophiolites, in the sense of massive layered sequences of pillow lavas, diabases, gabbros and peridotites, are not found on Timor, but serpentinites do occur along the north coast, while the coastal mountain block west of Manatuto is partly composed of amphibolites which are thought to be derived from basic rocks (A. B a r b e r, pers. comm. 1975).

The gravity pattern in Timor thus has much in common with that associated with the world's great ophiolite belts.

The steepness of the gradients, and, in particular, the small scale flexures west of Manatuto, are indicative of sources approaching very close to the surface, but although high density rocks do outcrop on the island the gravity maxima are displaced from these outcrops.

The amphibolites west of Manatuto may contribute to the gravity anomaly, but it is noticeable that the gradient is steep across their entire area of outcrop and there is no suggestion of a local closure.

By analogy with the ophiolite belts, it can be supposed that the Timor anomaly is due to one or more high density thrust sheets, fragments of which are represented by the

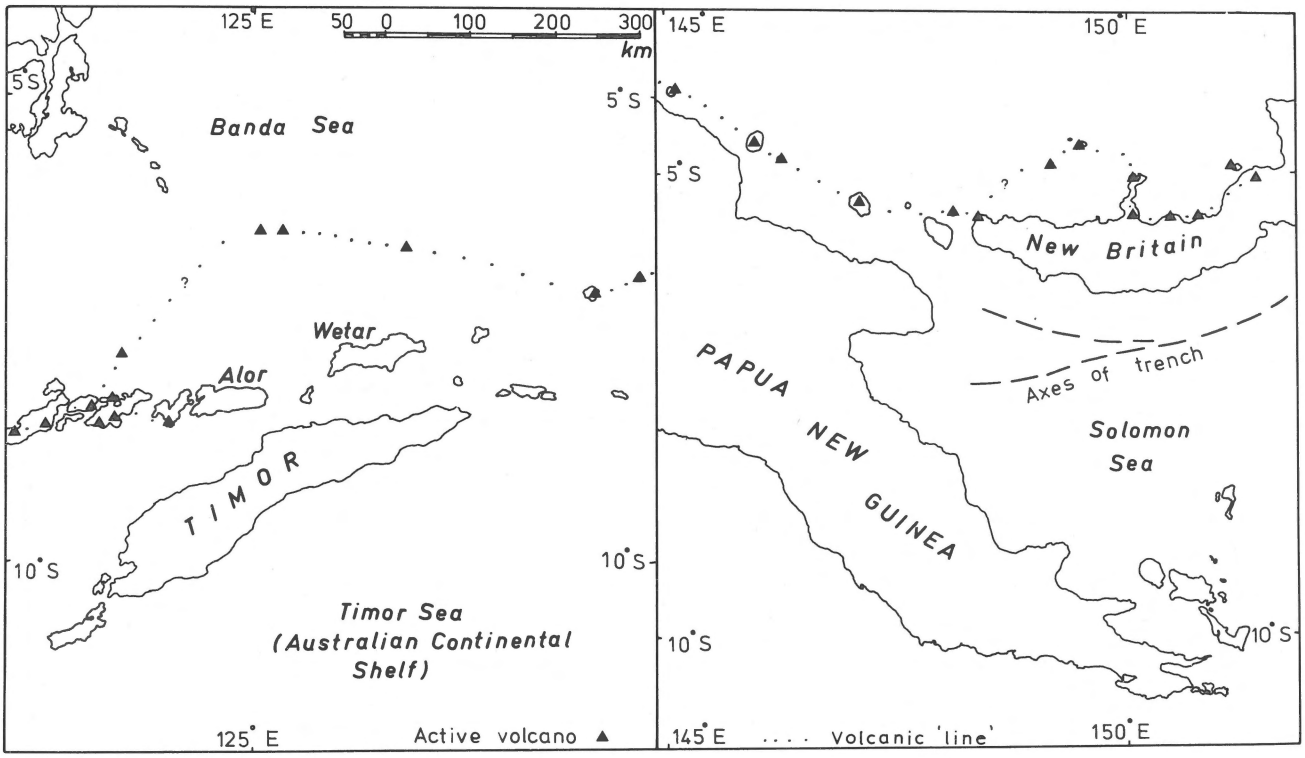

Fig. 2
Eastern Indonesia an eastern New Guinea, showing offsets in the volcanic arcs north of Timor and north of the trench bifurcation in the Solomon Sea.

amphibolites, serpentinised peridotites and pillow basalts in the north of the island.

The interpretation of the geology of Timor offered by Audley Charles (1968) and Carter et al. (1976) as a series of major thrust sheets resting ultimately on Australian continental basement, though not universally accepted (cf. Fitch and Hamilton, 1974; Grady 1975) accords well with such an interpretation.

3. Volcanic Patterns

In view of the supposed similarity in the tectonic situations of Timor and eastern Papua, it is interesting to consider the possible application of recent studies of New Guinea volcanicity to the Timor region. The Solomon Sea, which lies to the north of eastern Papua, is in turn bounded to the north by the New Britain trench, which parallels the south coast of the island of New Britain (Fig. 2).

This trench has most of the characteristics of an active subduction system, with a Benioff zone dipping at about 70° and active volcanoes to the rear of a non-volcanic frontal arc.

At its western end, however, the trench bifurcates and Johnson (1976) has concluded that the "Vitiaz" crustal fragment (named after the nearby Vitiaz strait) between the two arms is a detached slice forming part of neither major plate.

As discussed in detail by Johnson, the line of active volcanism, which runs along the north coast of New Britain and west through a chain of islands off the New Guinea coast, is displaced northwards by about 100 km opposite the supposed slice.

The presence of the slice, possibly extending deep into the mantle, presumably inhibits either magma generation or its ascent closer to the trench.

It has already been noted (Audley-Charles et al, 1972) that a similar but much more extensive displacement of a volcanic line occurs north of Timor, the inner arc islands of Alor, Wetar and Atauro being extinct while submarine and subaerial activity is currently localised 100 km further north, in the Banda Sea (Fig. 2).

If Johnson's slicing process were to be repeated several times it would clearly result in a system of overlapping thrusts as hypothesised for Timor, and the inner Banda arc volcanic offset would thus appear to constitute additional evidence in favour of this hypothesis.

In eastern Timor the proximity of the old inner arc can leave little room for further adjustment, but in the west movement is still taking place, as evidenced by the intense

shallow seismicity south of Lomblen and the continuing volcanic activity on that island and on Flores.

4. Discussion

The production of large coherent overthrusts, as found in Papua and New Caledonia and as claimed for Timor, appears to be a special form of response to stresses at a convergent plate margin.

In the case of Timor it would seem to have resulted from the impingement of the Australian continental margin, which is more buoyant than oceanic crust, on the subduction zone, and a similar explanation may hold in the case of the "slice" in the Solomon Sea.

The existence of the trough south of Timor suggests that currently the slicing process is being extended into continental crust, while the occurrence elsewhere of purely oceanic ophiolitic thrusts may be an indication of the failed subduction of recently formed, and therefore thermally buoyant, oceans or marginal basins.

Such large scale thrusts can and should be clearly distinguished from tectonic melanges formed in subduction zones by continuous accretion of material to the frontal arc from the downgoing plate.

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REFERENCES

Audley-Charles, M.G. (1968) – Geology of Portuguese Timor: Mem. Geol. Soc. Lond., 4, 76 pp.

Audley-Charles, M.G., D.J. Carter and J. Milsom (1972) – Tectonic development of eastern Indonesia in relation to Gondwanaland dispersal. Nature Phys. Sci., 239, 35-39.

Carter, D.J., M.G. Audley-Charles and A.J. Barber (1976) – Stratigraphical analysis of island arc-continental margin collision in eastern Indonesia. Jour. Geol. Soc. Lond., 132, 179-188.

Chamelaun, F., K. Lockwood and A. White (1976) – Bouguer gravity field of eastern Timor. Tectonophysics 30, 241-259.

Crenn, Y. (1953) – Anomalies gravimétriques et magnétiques liées aux roches basiques de Nouvelle-Calédonie. Annales Géophysiques, 9, 291-299.

Fitch, T.J. and W. Hamilton (1974) – Reply to comment on "Plate Convergence, transcurrent faults and internal deformation adjacent to southeast Asia and the Western Pacific" by T.J. Fitch. Jour. Geophys. Res., 79, 4982-4985.

Grady, A.E. (1975) – Reinvestigation of thrusting in Portuguese Timor. Jour. Geol. Soc. Aust., 22, 223-227.

Johnson, R.W. (1976) – Late Cainozoic volcanism and plate tectonics at the southern margin of the Bismarck Sea, Papua New Guinea. In "Volcanism in Australia" Ed. R.W. Johnson, Elsevier Publishing Co., Amsterdam 406 pp.

Milsom, J.S. (1973) – Papuan Ultramafic Belt: gravity anomalies and the emplacement of ophiolites. Geol. Soc. Amer. Bull., 84, 2243-2258.

Ritsema, A.R. (1956) – Two gravity profiles across Timor island. Verhand. Kon. Ned. Geol. Mijnbouw. Genoot., 15, 380-384.