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Gravity Traverse Along the United Arab Emirates Gulf Coast Between Diba-Khor Fakhan

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ABSTRACT. A 46 km gravity profile (based on 24 gravity stations) was established over the Tethyàn crust exposed along the Emirates coast of the Gulf of Oman from Diba to 8 km south of Khor Fakhan. A Bouguer gravity anomaly of about 30 mGal is noted across the profile which is interpreted in terms of shape and mass distribution of concealed part of the obducted nappe. A maximum gravity value was found over the maximum thickness of the nappe near Dadnah. Local gravity variations are interpreted as related to varyingly serpentinized portions of the main Semail peridotite. The geologic modelling of gravity values correlates well in terms of known thicknesses with the mappable ophiolite units of northern Oman.

Introduction and Geological Setting

Several geologic studies have been made on the Tethyan lithosphere in the northern and central Oman Mountains but only few geophysical efforts (Lippard, Shelton and Gass 1986; Khattab 1990; Shelton 1990; Manghnani and Coleman 1981) have been made. The gravity data, presented here are part of a continuing gravity survey being conducted by the author on the United Arab Emirates part of the northern Oman Mountains.

The general geology of the Diba Zone and adjacent areas belonging to the Middle and Upper Cretaceous overthrust zone (Searle *et al.* 1983; Robertson *et al.* 1990; Glennie *et al.* 1974 and Ministry of Petroleum and Mineral Resources 1976) and the local geology (Searle *et al.* 1983), beneath our gravity profile (denoted A-A′) are presented. Five major thrust units are recognized: 1) the Musandam shelf carbonates, an allochthonous Late Paleozoic-Mesozoic carbonate platform unit, 2) the Hawasina Complex, a complicated stack of thrust sheets of Mesozoic deep water carbonate platform slope, continental rise and abyssal plain sediments, 3) the Haybi Complex, comprising sedimentary and tectonic melange, alkaline and tholeiitic volcanics, and the greenschist facies forming the sole of the Semail ophiolite, 4) the overriding Late Cretaceous Semail ophiolite thrust sheet. Searle *et al.* (1983) identify that the thrust stack of oceanic rocks and the NE margin was produced by NW thrusting of the Arabian continental plate; more distal units were emplaced at progressively more higher structural levels. During the Mid Tertiary about 3.5 km thick sheet of Musandam shelf carbonates was thrust about 15 km westwards. The immediate surroundings of the A-A′ are devoid of Tertiary structures.

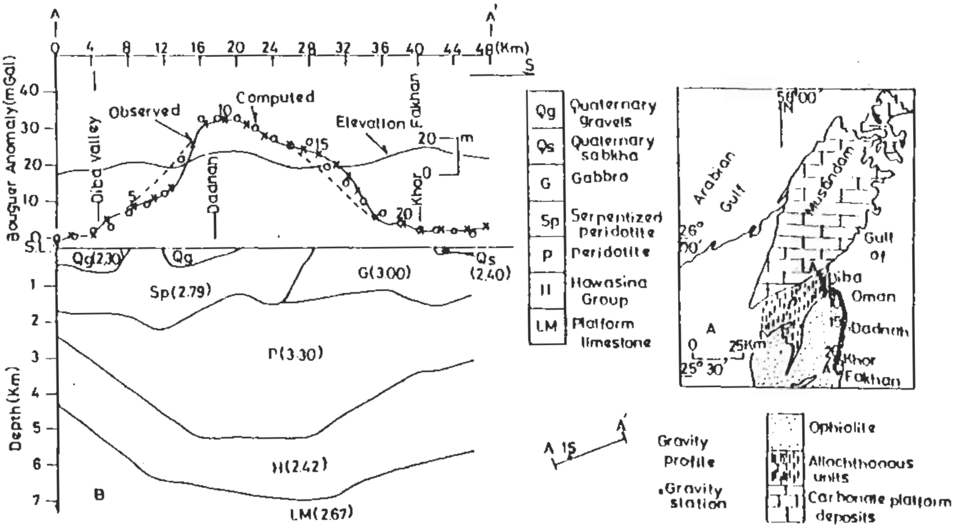

FIG. 1A. Outline Cretaceous tectonic map of northernmost Oman Mountains showing the location of 24 gravity stations. The Bouguer anomaly values at these stations (station 1 at Diba) are: 116.0, 116.6, 117.5, 121.0, 125.2, 126.9, 130.2, 141.1, 147.2, 149.1, 146.8, 144.1, 141.2, 140.5, 139.7, 136.1, 132.5, 129.1, 121.8, 120.5, 118.5, 118.8, 118.7 and 118.8 mGal respectively.

B. A gravity-derived cross section (A-A′) along part of the Emirates Coast of Gulf of Oman.

The 46 km long A-A′ profile commences near the axial part of the Diba Valley and passes by the towns of Dadnah and Khor Fakhan on the Gulf of Oman (Fig. 1A). The following formations (Searle *et al.* 1983) are crossed by the geophysical profile from north to south: Quaternary fluviatile deposits and beach sands, Semail ophiolite ultramafic and mafic suites, and coastal sabkhas. The first 8 km of this profile is represented by Quaternary and Recent sands. These deposits consist of boulders, gravels, sand and silt, drainage channels and minor undifferentiated terrace deposits, terrace piedmont gravel beds, scree and outwash fans, boulder to gravel size debris in a fine grained matrix and local sand and silt interbdes. The next 3 km of the profile are underlain by ultramafic serpentinized peridotite and serpentinite which are locally traversed by banded magnesite and thin chrysotile veins. Following this patch of Semail Ophiolite, the profile changes azimuth (to a southerly direction) to cross another Quaternary and Recent sediment patch of more or less same composition as the first outcrop (near the Diba Valley). Approximately 5 km south of Dadnah, the bedrock is serpentinized peridotite which is locally overlain by Recent beach sands and coastal sabkhas. These are followed by a major gabbroic exposure which underlies the southern 14 km of the traverse.

The gabbro is coarse grained leucocratic and melanocratic which is commonly layered and intercalated by minor serpentinite bands. Complex zones of gabbro with intermixed ultramafic rocks are also found. The last 6 km of the profile are covered by coastal sabkhas. These are calcareous silt, muddy sand with considerable salt content, salt crusts which are flooded by storm and spring tides.

The nearest observed gravity station to our profile (see Lippard, Shelton and Gass 1986) is at Al Khadrawaya (27° 48′N, 56° 40′E). The purpose of this paper is to correlate this gravity-derived crustal section with mappable ophiolite units in other parts of the northern Oman Mountains and to extend (to the north) the existing gravity data in central and southern Oman (Lippard, Shelton and Gass 1986; Shelton 1990; Manghnani and Coleman 1981).

Gravity Data

The A-A′ profile is 46 km long and is based on 24 gravity stations collected during the first quarter of 1990. These stations are averagely spaced at 2 km. The upper part of Figure 1B shows the distribution of gravity stations. A Worden (Master Geodetic) gravity meter with a range of over 6500 mGal, reading accuracy of ±0.01 mGal, drift rate of less than 2 mGal/month was used. No absolute pendulum reading was available.

A main base station near Diba was adopted as a reference reading whereas other subbases were established in the field for the purpose of making drift corrections. On a daily basis, the gravity stations were taken in the sequence ABCDE ... which proved to be satisfactory. Elevations ranged from 3.0 to 16.5m above sea level (Fig. 1B). The gravity stations were chosen at reliable elevation markers and road engineering level values on the United Arab Emirates topographic maps of 1:25,000 scale. The accuracy of each station elevation is believed to be within ±1.0m. The following corrections were used to reduce the observed gravity readings: drift, free air, Bouguer and latitude. Terrain corrections were not applied as the land topography encountered was generally smooth and gravity stations were established far enough from the relief surroundings.

The datum chosen is sea level. A density of 2.3 g/cc is assumed for making the Bouguer correction which is assumed to represent the low relief topography and the low density gravels (Hunting 1976). The assumed densities for other rock units in our model are taken from Manghnani and Coleman (1981) which are based on laboratory measurements. These density values are: 2.79 g/cc for the serpentinized peridotite, 3.30 g/cc for the unserpentinized peridotite, 2.42 g/cc for the Hawasina pelagic sediments. The autochthonous shelf carbonates (limestones) were assigned a density value of 2.67 g/cc. A base denstiy value of 2.67 g/cc was chosen.

Two dimensional polygonal approximation of the subsurface section was made (Talwani *et al.* 1959). The calculated gravity values are made at equal distances of 2 km (indicated by small circles). The elevation difference between topography and sea level is neglected since the observed small fluctuations between topography and sea level is found to have insignificant gravity effect. The parameters that are varied in the computed model (lower part of Fig. 1B) are the shape and thickness of the individual units and degree of serpentinization in the peridotite section. The computed geologic model is constrained by known geology and structure in the Emirates part of the northern Oman Mountains (Robertson *et al.* 1990; Glennie *et al.* 1974).

Discussion

A prominent and broad Bouguer gravity anomaly of about 30 mGal relief occupies a significant portion of our gravity profile (Fig. 1B). The axis of this anomaly is centered at about 22 km (from the northern tip of this profile, point A). As shown, gravity values range from near zero value near the axis of the Diba Valley (over the Quaternary gravels of the Diba Valley) to +32 mGal (at 2.5 km south of Dadnah) then to +4 mGal near the southern end of the A-A′ profile. No significant gravity regional is detected along our profile which may be related to the insufficient length of the profile.

The elevation profile does not exhibit large topographic variations and as indicated there is no apparent correlation between the gravity curve and the topography. Noted are local gravity variations which are superimposed on the main gravity anomaly. One can isolate graphically a low of –7 mGal between the Diba Valley and Dadnah and a high of +10 mGal between Dadnah and Khor Fakhan.

The inspection of the calculated gravity and the modelled cross section reveals a nappe whose thickness varies laterally. The highest gravity value is shown over the axis of the synform (maximum nappe thickness). The rapid fall of gravity values towards the axis of the Diba Valley suggests that the floor of this valley is devoid of high density ophiolite. A recent magnetic interpretation in the Diba Zone (Khattab 1992) has shown that the Diba Valley is underlain by 1.8 km of greenschist facies. According to Robertson *et al.* (1990), the Diba Valley is floored with allochthonous slope and basinal sediments with volcanics and metamorphics (see also Searle *et al.* 1983).

The local gravity low near the northern part of our profile is calculated as due to extensive serpentinization of the main peridotite body assumed to exist at depth. The maximum calculated thickness of the serpentinized peridotite exceeds 2 km and is shown to possess an irregular base. The local + 10 mGal anomaly is shown due to the sharp contact between the lower density serpentinized peridotite and the relatively higher density gabbroid exposure. The gabbro is found to attain a thickness of 1.5 km. The peridotite is calculated to extend to a maximum depth of 5.2 km and varies in thickness from 3.7 km near the axis of the synform to less than 0.7 km beneath point A. The two Quaternary patches near the northern end of the profile are shown to have a thickness of 0.5 and 0.2 km respectively. The southerly located inland sabkha deposit attains less than 0.3 km thickness. Clearly, the cause of the observed gravity fluctuation is the variation of the thickness of the high density ophiolite.

The indicated variation of thickness, incident to the modelled Tethyan nappe, along the surveyed part of the Gulf of Oman is worth investigating. A Tethyan nappe, along the Omani coast near Muscat was estimated from gravity data to extend to 8.5 km below sea level (Manghnani and Coleman 1981). These authors also delineated an ophiolite nappe near Alshinaz (24°.8 N) on the coast. The peridotite in this nappe reaches a thickness of 1.4 km. Recent gravity data (Shelton 1990), between 23°.5 N and 25° N on the Batinah coast in central Oman, indicates variation of Bouguer gravity values along the shore line of Gulf of Oman (–60 mGal at 23°.8 N, –30 mGal at 24°.2 N, –10 mGal at 24°.5 N and +100 mGal at 25° N).

The Hawasina Group is estimated to possess a thickness of 1.7 km at the axis of the synform. Magnetic modelling in the Diba Zone showed a subsurface section of the Hawasina Group of 2.8 km (Khattab 1992). The autochthonous shelf carbonates (LM) are adopted to have equal density as the base density of 2.67 g/cc; hence their configuration is not tested. An alternative interpretation of the observed 32 mGal gravity anomaly is subsurface mass deficiency (due to complete serpentinization of the peridotite) down to at least 5 km depth at both the northern and southern portions of our profile. This assumption cannot be ascertained on basis of available geologic data (Glennie *et al.* 1974).

Conclusion

The delineated gravity high centers around the thickest section of the outcropping ophiolite nappe. The local gravity variations which overly the main gravity anomaly are suggested as due to various degrees of serpentinization; an assumption substantiated by earlier investigations in other parts of the northern Oman Mountains.

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قـطاع جاذبي بمحاذاة ساحل الخليج بين دبا وخورفكان (الإمارات العربيـة المتحدة)

ممدوح خطاب

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المستخلص . أخذت قراءات جاذبية عند ٢٤ محطة بطول ٤٦ كيلو مترًا بين دبا وخورفكان على ساحل الإمارات لخليج عمان . وشوهدت شاذة بوجير بقيمة ٣٠ ميليجال ، حيث تم تقييم هذه الشاذة من واقع الشكل والانتشار الكثافي لأعضاء القشرة المحيطية لبحر التيثي . وبين هذا التقييم أن أقصى سمك لهذه القشرة يرتبط بالقيمة القصوى للشاذة وأن التغيير الجانبي المحلي للجاذبية له علاقة بدرجة السربنتنة لجسم البيريدوتيت الرئيس . وتتفق نتائج هذه الدراسة مع الحقائق الجيولوجية لبعض مناطق جبال عمان الشمالية .