Data Supplement item III for Ring et al. 2024

The Samail subduction zone dilemma: Geochronology of high-pressure rocks from the Saih Hatat window, Oman, reveals juxtaposition of two subduction zones with contrasting thermal histories. Earth Science-reviews

In this supplement item we provide the rationale and details of lithologic correlations of the Ruwi Nappe calcareous phyllite and the Yiti Nappe Mahil Formation, which are discussed in the main body of our manuscript.

Lithospheric strength contrasts are important in localizing and forming an intracontinental subduction zone. Therefore, Ring et al. (2023) suggested that Ruwi subduction commenced at a locus of pronounced strength contrast between the Al Aridh Trough and the Misfah Platform, the latter being hardly affected by Permo-Triassic extension and, therefore, had normal lithospheric thickness. In contrast, Breton et al. (2004) considered that the second, inboard subduction zone was positioned close to the Arabian Platform where gravitational instabilities might be less likely. To decide between the two possibilities, the potential protoliths of the Ruwi and Yity nappes could provide useful clues. The Ruwi Nappe is the oldest high-P nappe in the Saih Hatat window and its origin would help to pinpoint where subduction formed. The Yiti Nappe is also critical as it occurs above the oldest (Yenkit) Cretaceous shear zone. In the model proposed by Ring et al. (2023), the Yiti Nappe should be derived from the Misfah Platform.

Le Métour et al. (1986a, b), Goffé et al. (1998) and Searle et al. (1994) proposed that the Ruwi Nappe contains rocks of the mid-Turonian to Santonian (~92-84 Ma) (Robertson, 1987; Béchennec et al., 1992) Muti Formation. Ages of 99-96 Ma for waning high-P metamorphism (Ring et al., 2023) indicate that the Ruwi Nappe cannot belong to the Muti Formation. Searle (2019), Searle et al. (2022), and Searle (cited in Hacker and Gnos, 1997) considered the Ruwi Nappe as belonging to the Triassic Haybi complex of the distal rifted margin (Fig. 5 in main text and Data Supplement I). Yet another proposition by Ring et al. (2023) suggested that the Ruwi Nappe originated in the Al Aridh Trough (Fig. 5 in main text and Data Supplement I).

Searle (2019) regarded the Haybi complex near the continent-ocean transition as the most likely educt of the Ruwi Nappe, and also claimed that the Haybi complex is the protolith of the metamorphic sole. However, Ring et al. (2023) showed that the Ruwi Nappe and the metamorphic sole cannot have formed in the same subduction zone because they were subjected to vastly different P-T conditions at about the same time (8-10 vs 25-30°C km^{-1}) during the mid-Cretaceous. Therefore, the Haybi complex cannot be the protolith of both, the metamorphic sole and the rocks of the Ruwi Nappe. A late Cretaceous sedimentary mélange in the Haybi complex (see 2.1.2. in main text; Searle and Cox, 1999) is also difficult to reconcile with mid-Cretaceous waning high-P metamorphism of the Ruwi Nappe at >99-96 Ma. Le Métour et al. (1986a), Béchennec et al. (1992) and Rabu et al. (1993) described abundant volcanic rocks and chert from the Haybi complex, which do not match the dominant calcareous phyllite of the Ruwi Nappe. This calcareous phyllite does not show Bouma cycles and it is unlikely that the calcareous phyllite represents a trench mélange.

Potential protoliths for calcareous phyllite of the Ruwi Nappe

1) Umar Basin
2) Misfah Platform (Kawr Group/Safil Formation, Fm)
3) Al Aridh Basin
4) Baid Platform
5) Hamrat Duru Basin
6) Arabian Platform

Mélange of Ruwi Nappe

- **Matrix:** quartz-mica material, lenses of carpholite-bearing metapelites and lawsonite = a calc-phyllite which requires a calcareous protolith.
- **Clasts:** exotic blocks of Hawasina chert, limestone, sandstone, marbles, minor serpentinites, metaperidotite, metaconglomerates, and metabasalt blocks (with volcanic textures) (El-Shazly et al., 1990, 1994, 1995).

Metabasalt: relict amphiboles, interpreted to form during hydrothermal or ocean floor metamorphism (island-arc) of basalts prior to incorporation to melange (El-Shazli et al 1994).

Ruwi Protolith needs to be: shales, marls, marly/shaley limestones, and >99–96 Ma (Ruwi high-pressure, high-pressure metamorphism). Exotic blocks may be accreted to Ruwi HP after metamorphism (however, metabasalt and marbles probably not). Metabasalt could come from Triassic rifting volcanics from anywhere in the Hawasina Basin, or Saiq Fm (from platform).

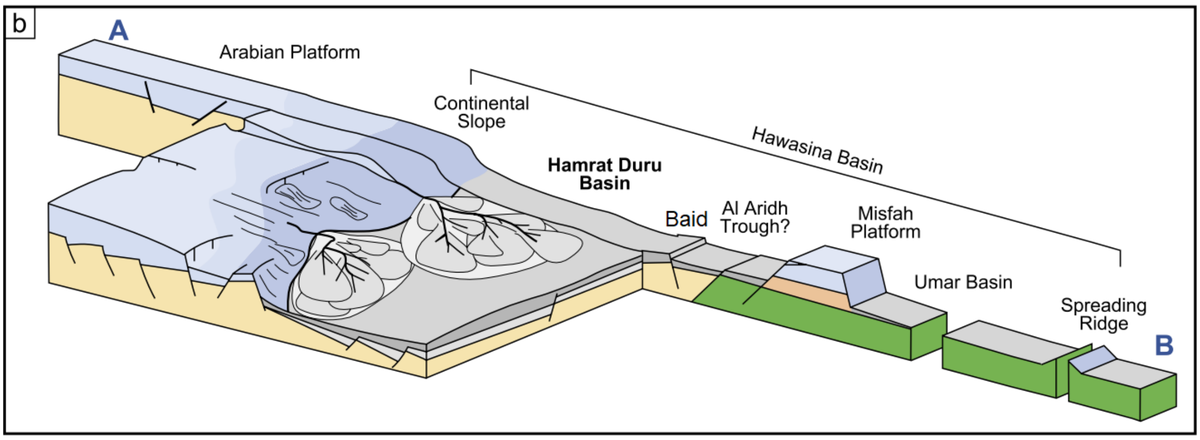

Fig. II-1. Schematic illustration of Oman rifted margin (from Blechschmidt et al., 2004; Scharf et al., 2021).

Compiled by Frank Mattern
(from Map sheets Seeb, Quryat, Nakhl, Fanja)

1) Umar Group (Haybi complex)

- Béchennec et al. (1992):
    - **Sinni Fm:** mainly volcanic rocks, several-m-thick shale with scattered blocks of white reefal limestone red radiolarian chert, beds of radiolarian chert with 1-10-cm clasts of white reefal limestone, meter-thick layers of red chert and calcirudite, which include clasts and blocks of reefal limestone, interbedded with lava.
    - **Aquil Fm:** megabreccia, calcirudites with boulders and blocks of shallow marine carbonates but predominantly radiolarian cherts and micritic limestone.

- Le Métour et al. (1986):
    - **“Lower Fm”:** volcanic rocks
    - **“Upper Fm”:** red radiolarian chert, fine-grained lithoclastic micritic limestone, chert.

- Rabu et al. (1986):
    - Mainly red radiolarian chert and micritic limestone; interbeds of shale;
    - igneous rocks.

2) Kawr Group

- Béchennec et al. (1992):
    - **MisfahFm:** volcanic rocks, shallow marine bioclastic limestone and dolomite, 1-m-thick microbeccia with carbonate and volcanic clasts.
    - **Nadan Fm:** white micritic limestone, some laterally discontinuous brown flint.
    - **Safil Fm:** 50 m thick; Turonian (94-90 Ma); some basal calcirudite, mainly pelagic clayey limestone (= pelagic argillaceous limestone). **Fm too young, Ruwi HP at 96 Ma**.

3) Al Aridh Group

- Béchennec et al. (1992):
    - **Sayfam Fm:** lower volcanic and upper largely carbonate member. The latter with megabreccia, calcirudite, radiolarian chert, micritic limestone with pelagic bivalves.
    - **Buwaydah Fm**: thick-bedded turbiditic calcarenite with flint nodules. Proximal turbidites with small ooids, pellets and lithoclasts of micrite and radiolarian chert and bioclasts.
    - **Musallah Fm:** radiolarian chert, calcirudites, which display grading.

- Rabu et al. (1986):
    - Partly chaotic limestone, gray limestone with variable brecchia content, dolomite, red radiolarian chert as interbeds in dolomite; olistoliths of white reefal limestone measuring up to 100 m.

4) Baid Fm

- Béchennec et al. (1992):
  - Shallow marine fusulinid-bearing carbonate, condensed cephalopod-bearing carbonate sequence.

- Rabu et al. (1986):
  - Mainly biomicritic or biomicrosparitic limestone in beds up to 2 m thick.

- Le Métour et al. (1986):
  - Light-colored sparry limestone (some micritic limestone), dolomitic limestone, microbreccia. Also limestone brecchia with reworked corals. Some dolomite, some black bioclastic limestone, some shale, some volcanic rock.

5) Hamrat Duru Basin

Al Jil Fm:

- Béchennec et al. (1992): Igneous rocks, calcirudite, megabreccia with boulders and blocks of Permian shallow marine carbonates, beige flaggy limestone and shale.
- Rabu et al. (1993): Igneous rocks, radiolarites.

Matbat Fm:

- Béchennec et al. (1992): Radiolarian chert, pelagic limestone, russet turbiditic quartz sandstone, shale, argillaceous siltstone, breccia.
- Rabu et al. (1993): Lithoclastic limestones with filaments, sandstone turbidite, lithoclastic limestone.

Guwayza Fm:

- Béchennec et al. (1992): Turbiditic oolitic calcarenite, calcirudites; micritic, in places silicified and marly limestone.
- Rabu et al. (1993): Largely oolitic turbidites, carbonate breccias.
- However, volumetrically small (a few beds in three cycles that are 40, 15 and 30 m thick and these beds are alternating with other lithologies).

Sidr Fm:

- Béchennec et al. (1992): Radiolarian chert, micritic limestone, turbiditic calcarenite.
- Rabu et al. (1993): Silicified limestone, micritic limestone, carbonate turbidite, radiolarite.

6) Arabian Platform

Mafraq Fm is too coarse and cannot be considered as related to the calcphyllite in question.

Salil Fm (Kahmah Gp) seems to show some matching lithologies:

- A sequence of alternating thin limestones, argillaceous limestones and marls (Forbes et al., 2010).

- Yellowish clayey limestone (yellow to grey-green clayey-silty limestone), blueish-black limestone, conglomerate (Le Métour et al., 1986).
- Calpionella-bearing argillaceous limestone (lower part) and bioclastic limestones (upper part) (Rabu et al., 1993).
- Kahmah Gp distinguished as Lower, Middle, Upper Fm's and are not correlated with named formations (e.g., Salil Fm) (Villey et al., 1986).
  - Lower Fm = micritic limestone.
  - Middle Fm = silty limestone, massive limestone, conglomerate limestone, clayey limestone.
  - Upper Fm = oolitic lst, bioclastic massive limestone.

Nahr Umr Fm (Wasia Gp). seems to show the best match:

- Forbes et al. (2010):

  "Clastic deposition dominated the whole shelf during most of the Albian. In Oman the Nahr Umr shales represent this clastic wedge, which provides a world class seal responsible for a large proportion of the retained hydrocarbons in the Oman subsurface. Carbonates were only present along the shelf margin. The Al Hassanat Formation in the Saih Hatat area of northern Oman is a platform-margin carbonate succession that has been interpreted as correlative with the Nahr Umr Formation (Immenhauser et al., 2000; Immenhauser et al., 2001).

- Lithology:

  The Nahr Umr Formation consists of varyingly calcareous shales, marls and some argillaceous limestones. All units are highly fossiliferous with abundant foraminifera, notably orbitulinids. A widely-traceable, thin, clean 'Marker' limestone lies within the lower 30 m of the Formation, but does not extend into South Oman. Towards the south and in the Al Huqf area outcrops, the Nahr Umr thins significantly (e.g., Nimr-1) and becomes more silt to sand prone (often with associated chamosite content as burrow fill or ooid grains). To the east of the Eastern flank/Al Huqf highs and in the extreme south of Oman, thicker limestone/claystone sections indicate a shift to a more proximal, platform edge, setting (e.g., Kulan-1).

- Wasia Gp not in Fanjah map area (Villey, M., Le Métour, J., De Gramont, X., 1986)

- Béchennec et al. (1992):

  Thickness on the northern flank Jabal Akhdar: 180 m. It starts with laminated argillaceous limestone containing accumulations of orbitolinids, and a fine-grained terrigenous detrital fraction, which includes white mica and quartz, along with bioclasts and rare pellets. The overlying sequence is 50 m thick and made up of interbedded 1 to 1.5 m thick beds of bioclastic limestone and meter-thick fissile argillaceous limestone. Massive limestone becomes predominant towards the top of the sequence, forming a 15-m-thick resistant unit. The two following sequences are 40 and 20 m thick, respectively, consisting of interbedded limestone and argillaceous limestone. The fifth and uppermost sequence is some 60 m thick and made up of 50-80 cm thick beds of nodular limestone and alternating with slightly argillaceous limestone.

References:

Béchennec, F., 1992. Roger, J., Le Mètour, J., Wyns, R. (1992). Geological map of Seeb, sheet NF 40-03, scale 1:250,000, explanatory notes, Ministry of Petroleum and Minerals, Directorate General of Minerals, Oman, pp. 104.

Blechschmidt, I. et al. (2004). Stratigraphic architecture of the northern Oman continental margin-Mesozoic Hamrat Duru Group, Hawasina complex, Oman. GeoArabia, 9, 81–132.

Forbes, G.A., Jansen, H.S.M., Schreuers, J. (2010). Lexicon of Oman Subsurface Stratigraphy. GeoArabia Spec. Publ. 5, pp. 370.

Le Métour, J., Villey, M., de Gramont, X., 1986. Geological map of Quryat, sheet NF 40-4D, scale 1:100,000, explanatory notes, Ministry of Petroleum and Minerals, Directorate General of Minerals, Oman, pp. 72.

Rabu, D., Nehlig, P., Roger, J., Béchennec, F., Beurrier, M., Le Métour, J., Bourdillon de Grissac, C., Teygey, M., Chauvel, J.-J., Cavalier, C., Al-Hazri, H., Juteau, T., Janjou, D., Lemière, B., Villey, M., Wyns, R. (1993). Stratigraphy and structure of the Oman Mountains. Bureau de Recherches Géologiques et Minières, Orléans Cedex, France, pp. 262.

Scharf, A., Mattern, F., Al-Wardi, M., Frijia, G., Moraetis, D., Pracejus, B., Bauer, W., Callegari, I. (2021). The geology and tectonics of the Jabal Akhdar and Saih Hatat domes, Oman Mountains. Geol. Soc. London. Mem. M54, 1–125. https://doi.org/ 10.1144/M54.

Villey, M., Le Métour, J., De Gramont, X. (1986). Geological map of Fanja, sheet NF 40-3F, scale 1:100,000, explanatory notes. Ministry of Petroleum and Minerals., Directorate General of Minerals, Oman, 68 pp.