

## Comment on “Eoalpine (Cretaceous) evolution of the Oman Tethyan continental margin: insights from a structural field study in Jabal Akhdar (Oman Mountains)” by Jean-Paul Breton et al.

David R. Gray and Robert T. Gregory

We commend Breton et al. (2004 in GeoArabia, volume 9, issue 2) for their lithospheric-scale presentation and interpretation of the tectonic development of North Oman. It is a significant and welcome advance in the geodynamic understanding of the obduction of the Samail Ophiolite, one of the largest and best preserved ophiolites.

We have however, two issues with the models presented in their Figure 8, but we point out that these are based on data that have only become available since submission of the Breton et al. manuscript. These new data require significant changes to parts of their proposed model. They are:

(1) *the timing of peak eclogite facies metamorphism*, and thereby the timing of “intracontinental” subduction.

Very recently published Sm-Nd garnet-garnet leachate-whole rock isochron ages of  $110 \pm 9$  Ma (5-point isochron) and  $109 \pm 13$  Ma (3-point isochron) from garnet-bearing eclogites at As Sifah (Gray et al., 2004b), require that subduction must have been ongoing at least by  $\sim 110$  Ma. These data restate that peak metamorphism is older than the crystallization age of the Samail Ophiolite, despite recently published Rb/Sr ages of  $78 \pm 2$  Ma (El-Shazly et al., 2001) and a SHRIMP U-Pb zircon age of  $79.1 \pm 0.3$  Ma (Warren et al., 2003).

Structural overprinting and metamorphic fabric relationships (see Miller et al., 1999; Gray et al., 2004a) indicate that previously published Rb/Sr ages of 78 Ma (El-Shazly et al., 2001) and  $^{40}\text{Ar}/^{39}\text{Ar}$  ages of 82 to 79 Ma (Miller et al., 1999) record the major NE-directed shearing event that partially exhumed the eclogites to a shallower crustal level. We therefore have interpreted the U-Pb SHRIMP zircon ages as recording rapid zircon growth at 82 Ma (after Gray et al., 2004b) and 79 Ma (after Warren et al., 2003) during high-P metamorphism, but at lower metamorphic grade with exhumation and the associated intense fabric development and non-coaxial top-to-the-NE shearing (see discussion in Gray et al., 2004b).

In summary, subduction must have been occurring in the period 120-110 Ma, and possibly prior to 130 Ma, thereby negating the late earliest to Middle Turonian timing of the “intracontinental” subduction zone of Breton et al. (2004) (step C of their Figure 8). This subduction may have been initiated during plate reorganization recorded by a change in the displacement of Africa with respect to Eurasia (Dercourt et al., 1986; Savostin et al., 1986, Figure 2).

(2) *the possible exotic nature of the Lower Plate* (includes the Huwl and As Sifah windows of Gregory et al., 1998; Miller et al., 1998; Gray et al., 2000; Gray and Gregory, 2003).

Felsic-schist (meta-tuffite) infolded with mafic schist, calc-schist and quartz-mica schist of the As Sifah Lower Plate region has yielded a U-Pb SHRIMP crystallization age of  $298 \pm 3$  Ma (Gray et al., in review). The metatuffs have previously been considered to represent Permian bimodal volcanism (Le Métour et al., 1986; Rabu et al., 1990), but this data suggests that the magmatism is older, possibly related to an older Late Carboniferous intracontinental rifting event. Distinctive negative  $\delta^{13}\text{C}$  values, and not strongly positive values characteristic of Permian carbonates of the Arabian platform (Richards et al., 2002) also suggest a possible unique pre-Permian stratigraphy. The As Sifah Lower Plate sequence may be part of an exotic micro-plate that was underplated to the Arabian margin during closure of the southern Neo-Tethys ocean.

If this is the case, then firstly current models of oceanwards-directed subduction of the Arabian margin (e.g. Breton et al., 2004) cannot easily derive and underplate this exotic lower plate, unless

subduction involves an outboard continental fragment. This is similar to one of the options discussed in Gregory et al. (1998). Secondly, the timing of the metamorphism and the possible subducted oceanic lithosphere (separating the outboard continental fragment from Arabia) obfuscates the need for a Middle Turonian intracontinental subduction.

### INCORPORATION OF AN OLDER HIGH-P METAMORPHISM

High-P metamorphism at ~ 110 Ma causes problems for most tectonic models of the Arabian margin, as it has been argued that there is no record either in the sedimentation or the volcanicity of an older subduction, and particularly one that operated for at least 20-30 My. There is clearly no constructional arc pile, such as observed in other, younger parts of the Tethyan realm, but this is a problem for tectonic scenarios involving subduction away from the margin, as well as towards the margin; i.e. it is a problem independent of the polarity of subduction.

In terms of the sedimentation though, it is interesting to note that tilting of the Arabian margin occurred during the Tithonian-Berrasian (150- 130 Ma), where the "margin acted as a single block" but with "no accompanying igneous activity" (Le Métour et al., 1995, p. 73). This was related to extension that caused flexure, principally drowning of the northern margin of the Jurassic platform and doming of the interior zones of the platform (Pratt & Smewing, 1993, p. 237; Le Métour et al., 1995, p. 73). This movement is also reflected by a marked unconformity in the shallow marine carbonate of the Jurassic platform (Pratt and Smewing, 1993; Le Métour et al., 1995). We speculate that this may represent the initiation of subduction in the outboard Neo-Tethys ocean at this time. Interestingly this "event" also coincides with the recorded change in plate motion of Africa with respect to Eurasia (Dercourt et al., 1986; Savostin et al., 1986, Figure 2).

Tilting of the margin also occurred at in the Albian- Turonian interval (Pratt and Smewing, 1993, p. 240) at a time when our Sm-Nd isochron age data suggest that high-P metamorphism was occurring in the lower plate rocks of the As Sifah window, Saih Hatat. Subsequently, a marked increase in subsidence rate in the Cenomanian, the period of Samail Ophiolite growth, is considered to represent downward flexure of the margin due to "the initiation of compression east of Oman" (Pratt and Smewing, 1993, p. 240).

In summary, there appears to be clear evidence in the sedimentary record that reflects tectonic activity that may not necessarily be related to margin extension caused by renewed rifting outboard in the Neo-Tethys ocean. We feel that the Arabian margin sedimentary record needs reinvestigation in light of these new geochronological data, particularly with the possibility of an older subduction system initiating sometime in the Tithonian-Berrasian period.

### PROBLEM OF INTRACONTINENTAL SUBDUCTION

As discussed previously, the plate tectonic model of Breton et al. (2004) requires development of a younger Middle Turonian intracontinental subduction system. Despite the major problems with the timing, there is perhaps also a problem in how this developed. Breton et al. (2004) proposed that intracontinental subduction occurred by lateral propagation of an oceanic subduction system into the Arabian continental margin (see their Figure 9). As they state that the propagation of such a subduction-related intracontinental tear or rupture "...would have rapidly died out due to, lighter weight and higher strength" of the continental lithosphere. As they state further, this means that the effects of subduction, and therefore the Campanian exhumation-related NE-directed shearing (see Figure 4a of Breton et al., 2004) does not occur along the whole mountain chain and should die out rapidly NW of Saih Hatat. However, their paper superbly documents cleavage and duplex-like imbrications in the Jabal Akhdar window that they relate to the NE-directed shearing.

We have documented NE-directed structures within both the pelagic units (Hamrat Duru Group) and slope facies units (Sumeini Group carbonates) in the Hawasina window (see Gray and Gregory, 2003, Figure 10) that suggests that such structures extend from Saih Hatat at least through to the Hawasina window.

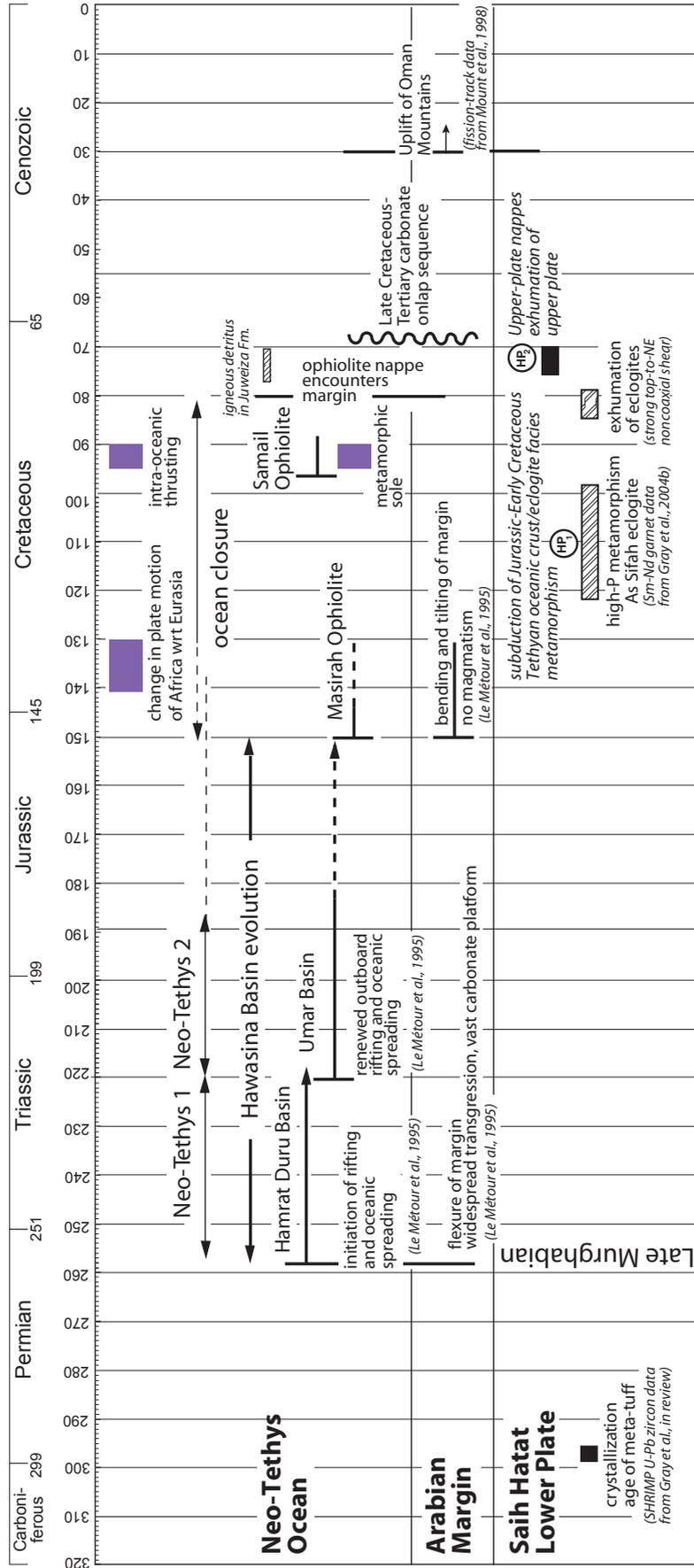


Figure 1: Time line diagram showing major tectonic activity and/or geochronological constraints for the tectonic evolution of the Arabian margin from 320 Ma to the present. The Neo-Tethys ocean, the northern Arabian margin and the Saih Hatat Lower Plate of Gregory et al. (1998) are treated separately, but with possible interconnections between the three tectonic elements highlighted.

## TIMING CONSTRAINTS ON TECTONIC EVOLUTION

The new data are summarized in Figure 1, with stratigraphic constraints from Le Métour et al. (1995), geochronologic data from Miller et al. (1999), Gray et al. (2004b) and Gray et al. (in review). These data provide the constraints for any tectonic model or any attempted restored or palinspastic framework as undertaken by Breton et al. (2004). The recognition by Breton et al. (2004) of the need for more than one crustal-scale thrust (subduction) system, either for reasons of timing or for mechanical reasons suggests that a single subduction interface to account for all of the metamorphism and the geometry is too simplified to account for the emplacement of the Oman ophiolite.

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## ABOUT THE AUTHORS

*David Gray is an Australian Professorial Research Fellow at the University of Melbourne and is currently researching links between obduction, lithospheric flexure and hydrocarbon basin evolution on the Arabian Peninsula. He graduated with a BSc (Honors) from the University of Newcastle, and a PhD in Structural Geology from Macquarie University. David lectured at Virginia Tech, USA between 1977 and 1983, and Monash University between 1983 and 2001. His research interests relate to rock deformation processes in the larger context of collisional orogenesis, with research in the Appalachian Orogen, the Otago Schist Belt of New Zealand, the Oman Mountains, the Damara Orogen of Namibia, SW Africa and the Tasman Orogen of eastern Australia.*



*drgray@unimelb.edu.au*

*Robert T. Gregory is Professor and Chairman of the Department of Geological Sciences, Southern Methodist University (SMU), Dallas, and Director of its Stable Isotope Laboratory. He holds a PhD from Caltech (1981) and has lectured at Monash University, Australia and SMU. He was a member of the USGS-National Science Foundation mapping team (1977-79) that produced the Muscat - Wahiba Sands transect 1:100,000 map (Bailey, 1981: JGR). With colleagues at Caltech, Robert published the first Nd, O, and Sr isotope profiles through a complete section of oceanic crust. He has conducted fieldwork in Oman and Saudi Arabia, as well as Australia, New Zealand and North America.*



*bgregory@mail.smu.edu*

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