Dating Methods

Homke *et al.* (2009) measured and dated more than 1500 m of stratigraphy in the Amiran anticline, and emphasised the need for multiple dating methods given the lithologic and sedimentary diversity of the succession. In addition, post-depositional processes resulted in remagnetization or isotopic resetting of different intervals of the succession (Homke *et al.*, 2009; Homke *et al.*, 2010), and thus a combination of different techniques of dating was needed to obtain confident results. During the course of the present study, more than 550 samples were collected for dating using large foraminifera, calcareous nannofossils, strontium isotope dating ($^{87}Sr/^{86}Sr$) and palynology. These samples were collected systematically in all logged sections.

Bioclastic and fossiliferous limestones and sandstones of all formations were sampled for dating using large benthic foraminifera. The samples studied were mostly taken from the Taleh Zang and Asmari Formation. The material was identified in thin section of rock samples and isolated centred specimens. Another set of samples was collected mainly in marlstones and marly limestones for calcareous nannofossils analysis throughout all marine formations of most of the studied sections. Slides of these samples were prepared using standard methods for calcareous nannofossil biostratigraphic analysis (Bown, 1998). In all cases, they were prepared from raw sediment, without centrifuging or shaking in order to avoid changes in the composition of the original assemblages. All the slides were analyzed under a Leica DMLP petrographic microscope at 1500X magnification (2000X magnification for observing details or to identify small species). The used calcareous nannofossil biozonation is based on standard timescales of the International Commission of Stratigraphy (Gradstein *et al.*, 2004).

Strontium isotope dating ($^{87}Sr/^{86}Sr$) was performed using samples of marine limestone from most formations. This method is based on the $^{87}Sr/^{86}Sr$ composition of marine authigenic sediments, recording the composition of the ocean at the time of mineral precipitation. The evolution of this composition has been well characterized as a function of time (e.g. Hess *et al.*, 1986; Hodell *et al.*, 1991; McArthur and Howarth, 2004). Once calculated the $^{87}Sr/^{86}Sr$ composition of the analysed samples, we used the most recent equation to calculate the age of the samples (McArthur and Howarth, 2004). This calibration has already proven to be successful in the Zagros belt by previous authors (Ehrenberg *et al.*, 2007; Homke *et al.*, 2009). Analyses were performed by the Laboratorio de Geocronología y Geoquímica Isotópica of the Universidad Complutense de Madrid in Spain. In the field, sampling was done in fresh and unaltered rocks, trying to avoid samples close to karsts, to minimize the effects of post-depositional processes. Palynologic dating was performed from samples of shales and marls of the Gurpi, Amiran, Taleh Zang and Kashkan formations. These analyses were performed by Millennia Consultants LCC (Rowsham, England). The biozone scheme used to date the palynologic sequence was constructed for the Middle East, and is based on Gradstein et al. (1995) timescale.

Accuracy of dating methods utilised

The lithologic (siliciclastic to carbonate) and paleoenvironmental (deep marine to continental) variations within the Amiran Basin infill constrain the applicability of the four used dating techniques. However, when complementary methods are used mismatches between the obtained ages may arise. To overcome this problem, we established a hierarchy based on the exactitude and restrictions associated to the used methods. Calcareous nannofossils and large foraminifera biostratigraphies were selected as the most determinant methods, as we believe them to be the most precise and the obtained biostratigraphic ages are self-consistent, with clearly younging-upsequence assemblages in all studied successions (eg. **Fig. A.1**, **Fig A.2**). Strontium isotope dating is the most precise of the used methods to date carbonate layers, although some method limitations must be taken into account. From the end of the Eocene to Present, $^{87}Sr/^{86}Sr$ in seawater has increased monotonically, thus allowing accurate dating of well-preserved authigenic marine carbonates. However, the period of deposition of most of the Amiran basin infill corresponds to two major oscillations in the $^{87}Sr/^{86}Sr$ composition, which may result in five possible ages for a dated sample (**Fig. A.3**). Thus, when one of the obtained possible age ranges was in good agreement with the other methods we selected that age range as the most probable. Besides, since diagenetic processes and potential isotopic resetting were not evaluated in detail when mismatches occurred, we did not use $^{87}Sr/^{86}Sr$ ages. Palynologic biostratigraphy was mainly selected to date the continental sediments of the Kashkan Formation, since alternative methods such as magnetostratigraphy were unsuccessful when proved in the Amiran anticline (see discussion in Homke *et al.*, 2009). The results from palynostratigraphy were not precise and sometimes not self-consistent and thus giving a significant wide range of ages that did not help significanlty for dating. In addition, the results must be taken into account very carefully if we add the climate-controlled anachronism of the stratigraphic distribution of taxa in the Paleogene (*e.g. Gradstein et al.*, 2004).Therefore, when palynostratigraphy was not in agreement with more robust age determinations we did not use it.

Despite these problems, a significant amount of new results were generated to date the sedimentary infill of the Amiran basin, and provided a solid basis to separate six well recognized time intervals. Obtained dating results show that each of the used methods was adequate for a different interval of the stratigraphic succession: calcareous nannofossils for the basinal Gurpi, Pabdeh and Amiran formations, large foraminifera for the platforms of the Taleh Zang Formation, palynology for the continental Kashkan Formation, and strontium isotopes ($^{87}Sr/^{86}Sr$) for the largely expansive carbonate Shahbazan and Amiran Formations, especially above the Eocene-Oligocene boundary.

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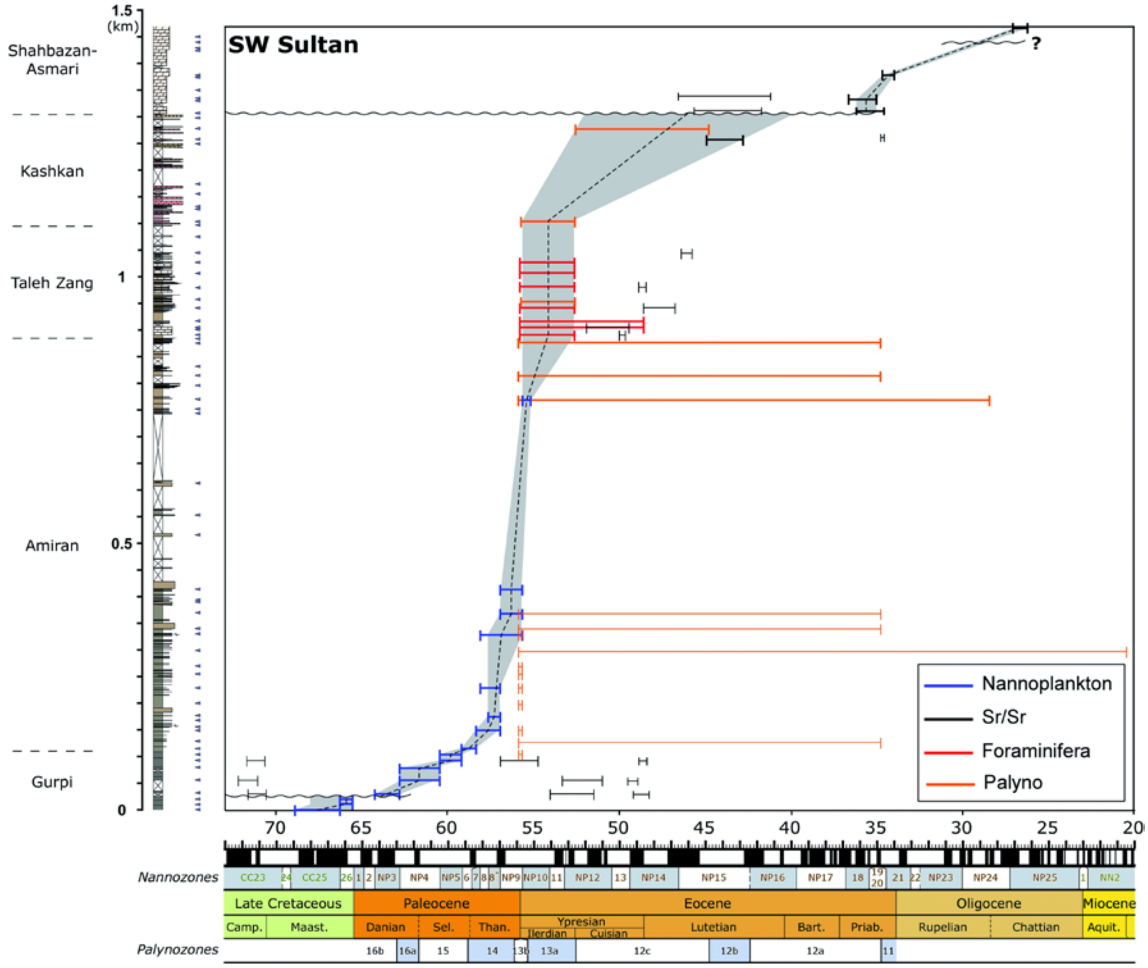

Fig. A1.- Correlation of the SW Sultan stratigraphic log to the geological time scale, using biostratigraphy and strontium isotope composition. The grey band shows the range of possible ages.

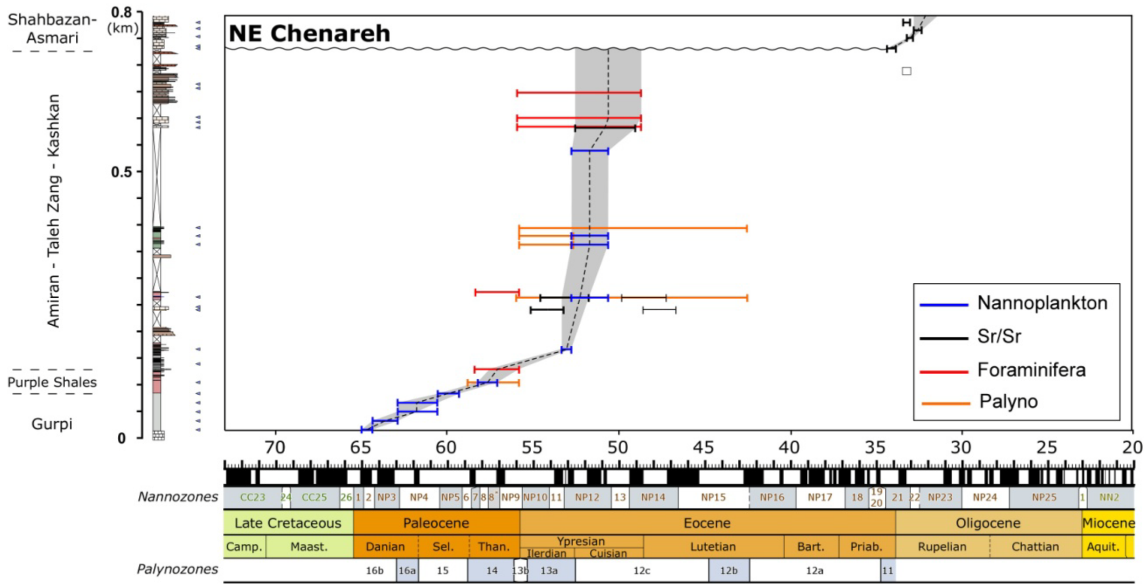

Fig. A2.- Correlation of the NE Chenareh stratigraphic log to the geological time scale, using biostratigraphy and strontium isotope composition. The grey band shows the range of possible ages.

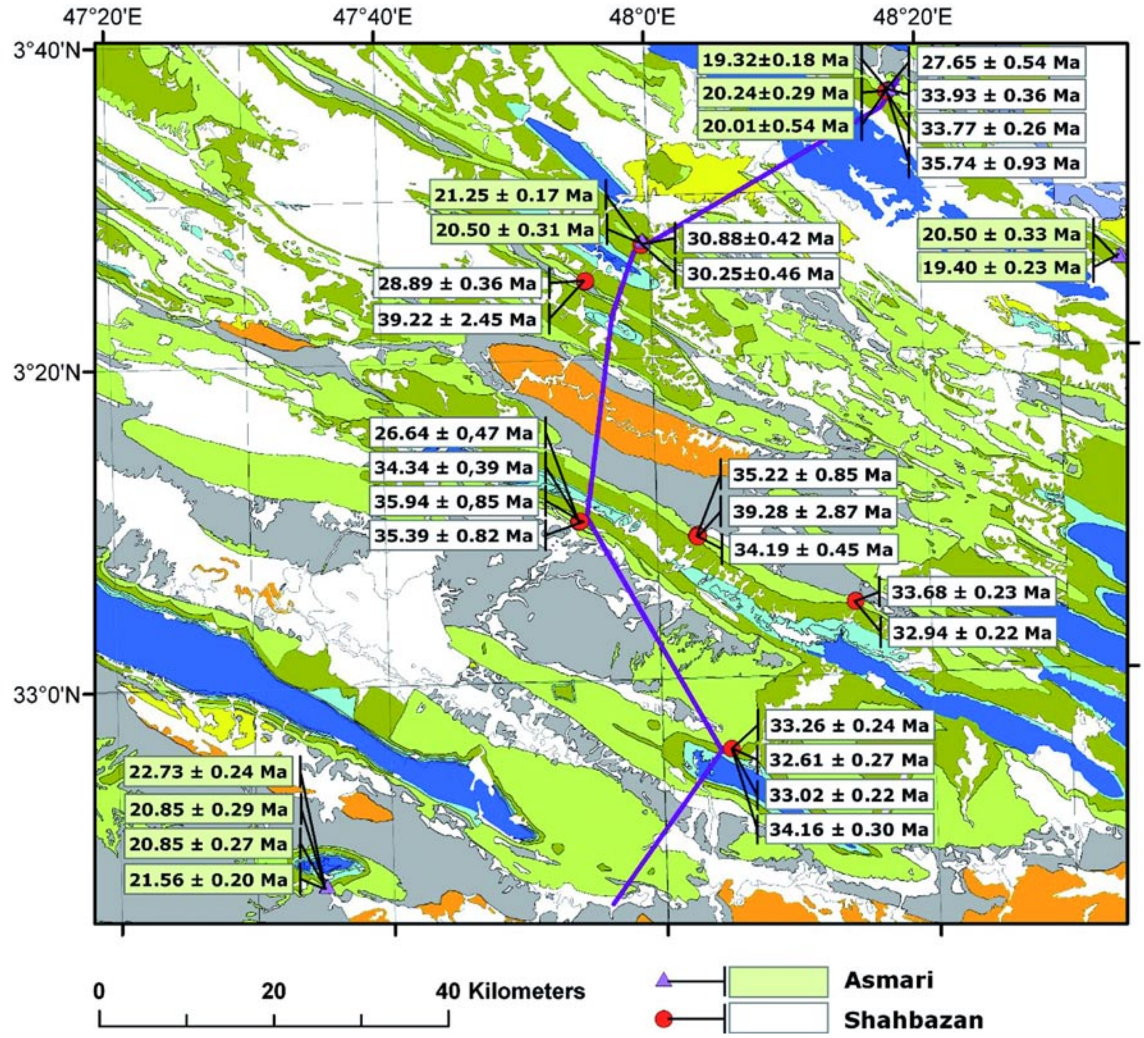

Fig. A3.- Map showing the distribution of $^{87}Sr/^{86}Sr$ ages for the Shahbazan and Asmari formations. When multiple ages occur in the same site, they are listed by stratigraphic position.