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Multilayer Properties Revealed by Anticline Distribution, the Case of the SE Pusht-E Kuh Arc (Lurestan)

E. Casciello* (CSIC), J. Vergés (CSIC), E. Saura (CSIC), G. Casini (CSIC), N. Fernández (CSIC), E. Blanc (Statoilhydro, GEX), S. Homke (StatoilHydro) & D.W. Hunt (StatoilHydro)

SUMMARY

Folding in the south-eastern Lurestan Province was analysed by measuring anticline s wavelength and axial-length and by comparing the fold distribution with the available paleofacies maps. It was found that the large variability of the measured parameters occurs in relation with facies changes within the Cretaceous Bangestan Group, which acts as the competent carbonate unit that governs buckling in this region. The Oligocene-Miocene Shahbazan-Asmari unit folds harmonically with the Bangestan Group, except in the areas where the Paleogene deposits interposed between the two units exceed 1300m of thickness. In these areas the Shahbazan-Asmari carbonate displays short wavelength folds that indicate a complete decoupling from the underlying folds of the Bangestan Group. It is suggested that this decoupling occurs because the summed thickness of the incompetent units separating the Shahbazan-Asmari from the Bangestan Group exceeds the extension of the effective zone of contact strain of the Bangestan Group folds.

Introduction

The Zagros mountain range is a NW-SE trending segment of the Alpine-Himalayan suture originating from the Late Cretaceous-Cenozoic convergence of the Arabian and the Eurasian plates, which led to the closure of the Neotethys ocean and to plate collision (Golonka, 2004). The south-western side of this suture, in Iraq and Iran, is occupied by the Simply Folded Belt, an elongated region extending almost 2000km with spectacular trains of folds developed in a thick multilayer of Paleozoic to Cenozoic sediments (Fig. 1a). These large folds, which contain a large proportion of the Middle-East oil reserves, were originally interpreted as detachment folds generated by the buckling of competent units above a weak detachment located at the base of the sedimentary cover (Colman-Sadd, 1978). However, further studies conducted in the Fars region and in the central Zagros (Sherkati et al., 2005; Sepehr et al., 2006; Carruba et al., 2006) indicate that various detachment levels exist in the sedimentary cover, and that the fold's geometry, size and distribution is intimately related to the mechanical properties of the folding multilayer. The characteristics of folds in the Pusht-e Kuh Arc (Fig. 1a) have been analysed in terms of fold shape and amplitude (Vergès et al. submitted); in this contribution we analyse fold characteristics in map view and compare these data with the facies distribution and other relevant stratigraphic parameters to better understand the relation between folding and mechanical stratigraphy in the southern Lurestan Province.

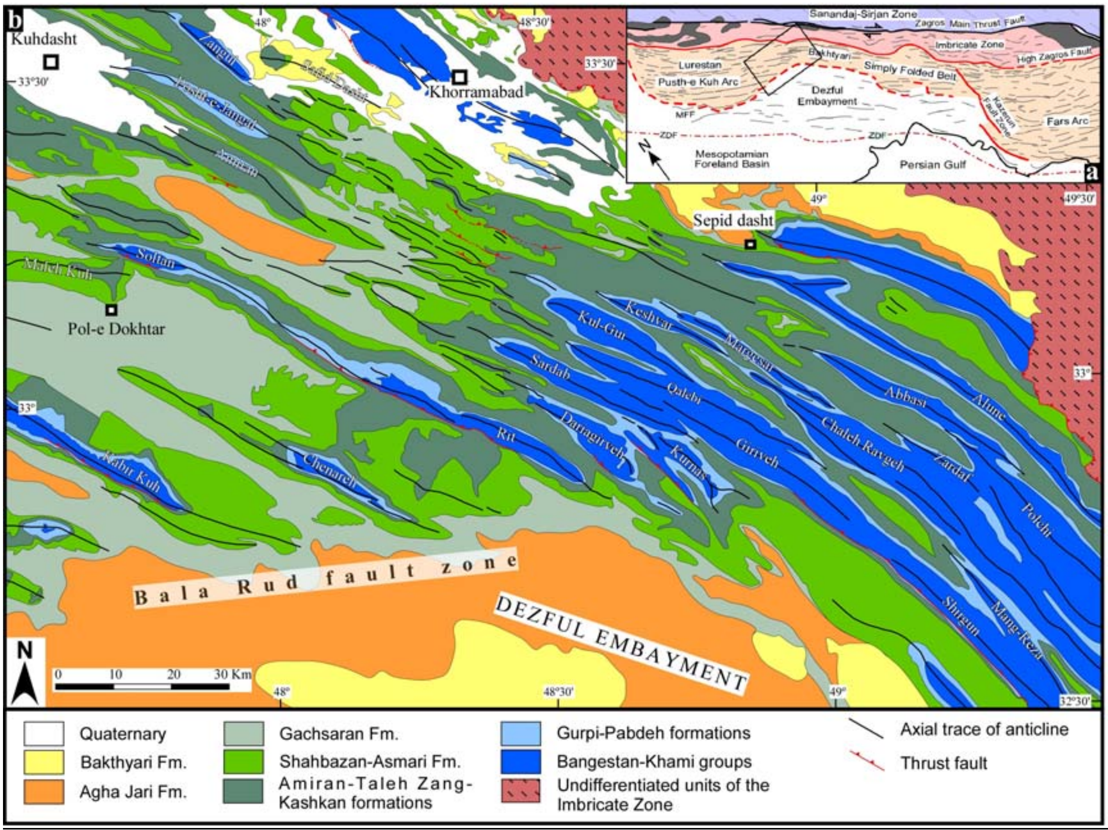

Figure 1. **a** – Tectonic sketch of the Zagros range. **b** – Geological map of the studied area obtained from NIOC geological maps and satellite imagery.

Fold patterns in the south-eastern Pusht-e Kuh Arc

The southern Lurestan Province is particularly interesting as it contains the transition between the Pusht-e Kuh Arc and the Bakhtyari culmination, accompanied by a rapid change in the level of exposure along the folds trend (Fig. 1b). This change in exposure level allows comparing, across a relatively short distance, the characteristics of folds developed within the two carbonate units that form the upper and lower reservoir units throughout the Zagros: the Bangestan Group and the Shahbazan-Asmari unit. It must be noted that these two carbonate units represent the only major competent units in a stratigraphic succession that is otherwise dominated by clastic deposits, shales, evaporites and subordinate pelagic limestones (Fig. 2). The parameters that were used to analyse fold distribution are the axial-length and the wavelength of anticlines, measured from their axial traces. These were obtained from NIOC geological maps and were successively modified and integrated through the analysis of 3D stereo (Spot5) satellite images and field surveys. The graphic in figure 3 shows the wavelength and axial-length of 42 anticlines located within the area of Fig.1b. Both parameters show a large variability: wavelengths range from a minimum of 870m to a maximum of 15km, and axial-lengths vary from few hundred meters to almost 100km. Despite the large dispersion in these values, in map view it is possible to distinguish domains characterised by an approximately homogeneous fold wavelength and length. Observing the geological map in figure 1b it can be seen that an important change in the spacing of anticlines occurs along the northern side of the Soltan-Rit anticline. The region to the north-east of this boundary is characterised by tightly packed anticlines separated by extremely narrow, pinched synclines. By contrast, the few anticlines located to the south-west of the Soltan-Rit anticline appear widely spaced and with an axial length above the average of the main cluster in figure 3. The Soltan-Rit and Kabir-Kuh anticlines also present evidence of thrusting along their forelimbs (Fig. 1), however, field analysis and section construction indicate that the amount of displacement along these faults is very limited, generally inferior to 1km and not exceeding 2km (Vergés et al., submitted). In the area south of Khorramabad city an anomaly in the distribution folds can be noted (Fig. 1b). The Shahbazan-Asmari carbonate, which generally folds harmonically with the Bangestan Group, is deformed by short wavelength (average 2km) and short axial-length folds (<20km; Fig. 3) that are positioned above large anticlines of the Bangestan Group with wavelengths in excess of 5km, indicating, therefore, a complete decoupling from the Bangestan Group in this specific area.

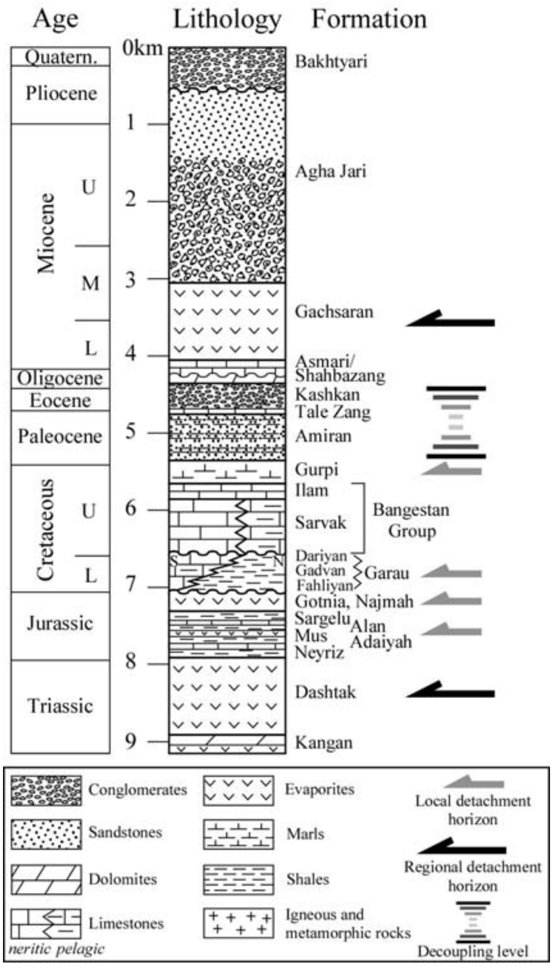

Figure 2. Mesozoic to Recent stratigraphy of the southern Lurestan area, based on data published by Homke et al. (2004), Homke et al. (in press), well data (Samand 2, Kabir Kuh 1) and isopach maps published by Koop and Stoneley (1982).

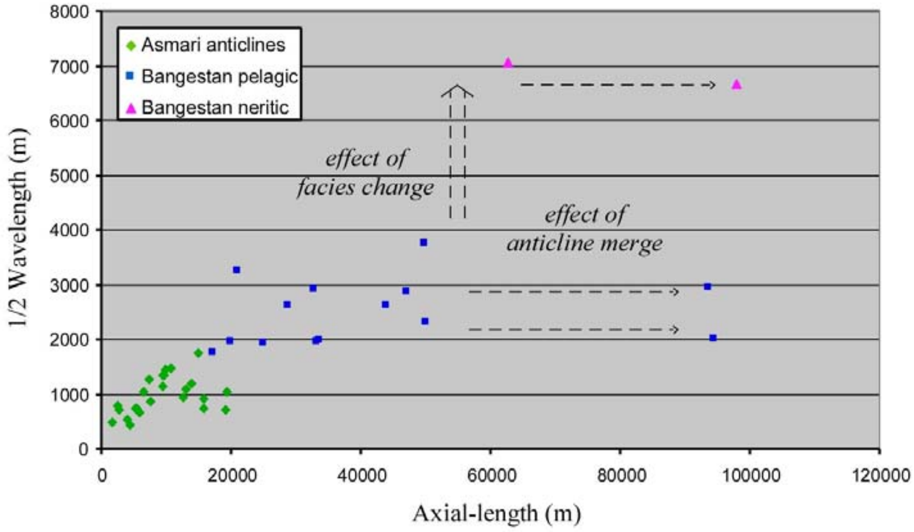

Figure 3. Wavelength and axial length of 42 anticlines of the south-eastern Pusht-e Kuh Arc.

Discussion

To analyse the large variability displayed by the folds in the study area a comparison was made between the distribution of folds and the facies of the Mesozoic stratigraphic units. Published paleo-facies maps (Koop and Stoneley, 1982) and field surveys indicate that the north-eastern flank of the Soltan-Rit anticline represented a facies boundary during the Late Cretaceous, separating a carbonate platform to the south-west from a pelagic area to the north-east. The available data indicate also that there is no significant thickness variation across this facies transition (Koop and Stoneley, 1982). The short wavelength of the anticlines located to the north-east of the Rit anticline (Fig. 1b) reflects, therefore, the reduced competence of this pelagic facies and the higher degree of anisotropy induced by the smaller bed thickness and the frequent shale partings. Conversely, the higher competence of the carbonate platform facies is reflected by a higher spacing between anticlines and the development of thrust structures in the forelimb of anticlines.

Regarding the variation in folding behaviour of the Shahbazan-Asmari carbonates, from perfectly coupled with the Bangestan Group to completely decoupled, its cause was searched within the Paleogene stratigraphic units (i.e. Amiran, Taleh Zang, Kashkan formations; Fig. 2) that separate the two competent carbonate units. Isopach maps of the Amiran and Kashkan formations were constructed, using a large database of thickness measures deriving from fieldwork, unpublished reports and remote sensing. The latter were carried out using 2,5m resolution satellite images (Spot5) and a 25m resolution DEM. Field based control measures indicate that these remotely sensed measures have accuracy in the range of 5-15%. The Taleh Zang Formation was considered unsuitable to compile an isopach map due to the frequent changes in thickness and the overall small thickness (average < 200m) of these deposits. By comparing the isopach map containing the summed thickness of the Amiran and Kashkan formations with the map distribution of axial traces it was found that the short wavelength folds within the Shahbazan-Asmari carbonates develop only where the thickness of the Paleogene deposits exceeds 1300m. Unless compositional changes within the Paleogene deposits are invoked, it is reasonable to infer that the change in folding behaviour of the Shahbazan-Asmari is related to the variations in thickness of the relatively incompetent units that separate it from the Bangestan Group.

Conclusions

Fold patterns of the southern Lurestan region, expressed in terms of axial-length and wavelength distribution, reflect the characteristics of the sedimentary multilayer in which they formed. Within the carbonate deposits of the Bangestan Group the transition from pelagic to neritic facies determines a threefold increase in anticline wavelength and may be associated to the development of thrust structures in the forelimb of anticlines. The Shahbazan-Asmari carbonates fold harmonically with the Bangestan Group. However, in areas where the Paleogene deposits exceed 1300m in thickness, the Shahbazan-Asmari unit displays short wavelength folds indicating a complete decoupling from the underlying folds of the Bangestan Group. We interpret this disharmony in folding as indicating that 1.3km represents the critical thickness above which the strain originated by buckling of the Bangestan Group, and transmitted through the Paleogene deposits, is insufficient to influence the folding at the Shahbazan-Asmari level. The results of this study document how the distribution and the characteristics of structures can provide extremely useful indications on the architecture and rheological behaviour of the geological multilayer in which they formed.

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