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Interaction of the Zagros Fold–Thrust Belt and the Arabian-type, deep-seated folds in the Abadan Plain and the Dezful Embayment, SW Iran

Iraj Abdollahie Fard[1], Alvar Braathen[2], Mohamad Mokhtari[3] and Seyed Ahmad Alavi[4]
[1]*National Iranian Oil Company, Exploration Directorate, Tehran, Iran (e-mail: iabdollahi@niocexp.org)*
[2]*Centre for Integrated Petroleum Research, University of Bergen, Norway (e-mail: alvar.braathen@cipr.uib.no)*
[3]*International Institute of Earthquake Engineering and Seismology, Tehran, Iran (e-mail: mokhtari@iiees.ac.ir)*
[4]*Shahid Beheshti University, Earth Sciences Faculty, Tehran, Iran (e-mail: a_alavi@cc.sbu.ac.ir)*

ABSTRACT: The Dezful Embayment and Abadan Plain (SW Iran) contain major parts of the remaining Iranian oil reserves. These oil provinces are characterized by two types of structural closure: very gentle N–S- to NE–SW-trending basement-cored anticlines (Arabian-type highs) in the SE; and open to tight, NW–SE-trending thrust-related folds in the NE (Zagros Fold–Thrust Belt; ZFTB). Most deep-seated anticlines are upright and symmetrical in Cretaceous and older units. In some cases they reveal steep faults in their core which, in the light of regional observations, suggest that the basement is involved in the faulting. Untested plays around these anticlines include reefal build-ups, debris flows, truncated sedimentary sections and onlapping clastic units.

The ZFTB shows a classic structural style, with overall shortening reflected in thrust displacement declining from the Dezful Embayment towards the frontal zone in the Abadan Plain. The Early Cambrian Hormuz Salt represents the fundamental sole for the fold–thrust belt and locates major fault-propagation folds in the southwestern Dezful Embayment. These folds represent the main petroleum target of the area. Another important unit is the Mid-Miocene Gachsaran Formation. This detachment reveals both in-sequence and out-of-sequence thrusting. Interaction of deep-seated anticlines and fold–thrust structures results in thrust imbrications and formation of duplexes within the Gachsaran Formation when thrusts abut deep-seated anticlines. Above the crest of the anticlines, thrusts are forced up-section into syn-tectonic deposits, whereas the forelimb reveals out-of-the-syncline thrusts. Several petroleum plays are identified in such zones of structural interaction, including anticlines above buttress-related duplexes, out-of-sequence imbricate thrust fans with associated folds above major anticlines, truncation of footwall layers below potentially sealing thrusts, and sub-thrust anticlines.

KEYWORDS: *Zagros Orogeny, SW Iran, fold–thrust belt, structural interaction, petroleum plays*

INTRODUCTION

This paper aims to unravel the geological characteristics that make the Dezful Embayment and Abadan Plain (study area) a major petroleum province. It is a region that contains numerous untested plays. The study area is located along the northeastern margin of the Arabian platform (SW Iran) (Figs 1 and 2). Geologically, the area is positioned between the Precambrian Arabian Shield to the southwest and the Zagros Fold–Thrust Belt (ZFTB) to the northeast. Since the 1940s, the economical potential of the Dezful Embayment and Abadan Plain has been proven by considerable oil discoveries, such as the Ahwaz and Marun oil fields. Although the region has been studied intensively over the last decades, with numerous 2D and 3D seismic surveys, there is still a significant unexploited potential. The comprehensive database discussed here significantly expands on limited published data; it is basically new to the international community. More than 25 000 km of 2D seismic profiles and 2200 km^2 of 3D seismic data from the National Iranian Oil Company (NIOC) have been interpreted. The seismic interpretations are supported by well data. Aeromagnetic and gravity maps, including a merged gravity map of Iran, Iraq and Kuwait, have also been studied.

These datasets are used to shed light on structural trends and various mechanisms behind the development of Arabian-type, deep-seated anticlines. These folds are, in many places, seen to interfere with layer-parallel and low-angle thrusts and associated major fault-propagation folds of the ZFTB. Interaction between deeply rooted anticlines and layer-parallel thrusts triggers fold decapitation, local layer-parallel thickening (imbrications, duplexes), out-of-sequence thrusts and thrusts ramps into the syn-tectonic section. The paper concludes with a

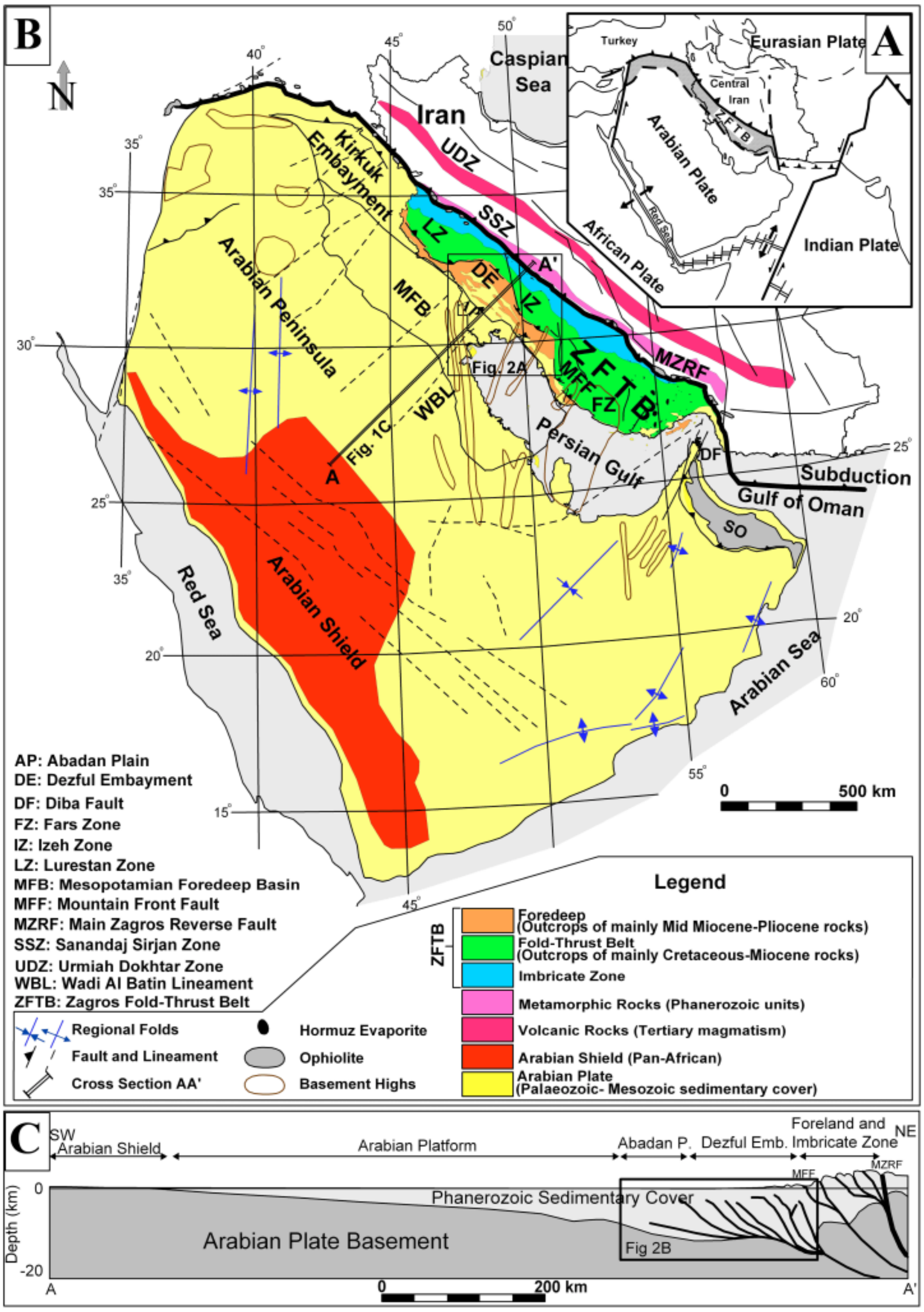

Fig. 1. (**A**) Map showing the Zagros Fold–Thrust Belt (ZFTB) along the northeastern margin of the Arabian Plate. (**B**) Generalized tectonic map of the Arabian Plate and main structural subdivisions of the Zagros orogenic system. Location of Figure 2A is indicated. (**C**) Simplified cross-section across the Arabian Shield, Arabian Platform and the ZFTB along line A–A′. The Arabian Shield exposes the Precambrian Arabian basement in the SW. The depth to basement increases towards the Dezful Embayment, whereas the basement is shallower due to its location in thrust sheets in the NE.

discussion concerning untested petroleum traps of the region, including stratigraphic traps linked to growth of Arabian-type, deep-seated anticlines, and structural traps of deep-seated folds and thrust anticlines. The potential represented by structures generated by interaction of these fundamentally different structures is also discussed.

REGIONAL SETTING

The Zagros Orogen is situated in the Himalayan–Alpine orogenic system, which extends continuously from eastern Turkey to southern Iran, for a distance of almost 2000 km (Fig. 1A). This orogenic system was formed by the closure of the Tethyan Ocean and the subsequent collision between Afro-Arabia and Eurasia (Takin 1972; Berberian & King 1981). In the case of the Zagros Orogen, ocean closure was fulfilled and the region experienced continent–continent collision. In contrast, in the southeast, oceanic crust is still subducted under the Iranian Plate along the Oman Subduction Zone (Fig. 1B).

The Zagros Orogen is built up of three parallel belts (Alavi 2004): (1) the Urmieh–Dokhtar Zone consists of Tertiary magmatic assemblages; (2) the Zagros imbricate zone includes the Sanandaj–Sirjan zone of thrust faults – these thrusts transport numerous nappes of metamorphosed and non-metamorphosed Phanerozoic stratigraphic units of the Afro-Arabian passive continental margin (Alavi 1994); (3) the ZFTB forms the less strained, external part of the orogen. The fold-thrust belt reveals a tectonic wedge of folded and faulted sedimentary rocks (Fig. 1B), characterized by SW-directed thrusting. Regional contraction has developed from the Pliocene to Recent, and the fold–thrust belt is currently experiencing north–south shortening at rates of 4 ± 2 mm a^{-1} in the western part, to 9 ± 2 mm a^{-1} in the eastern part (Masson *et al.* 2005).

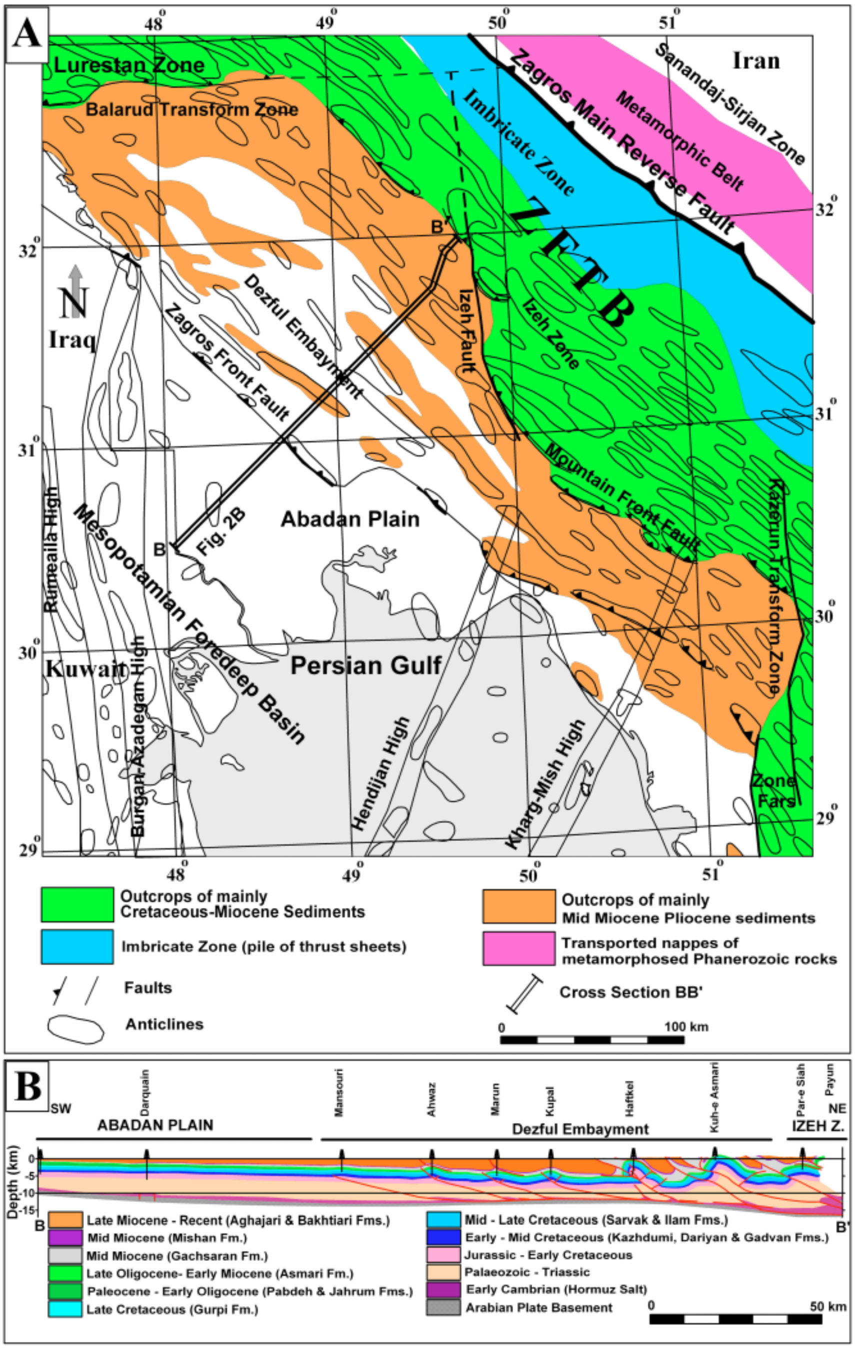

Fig. 2. (**A**) Simplified geological map of the western ZFTB modified from the National Iranian Oil Company (NIOC) geological map of SW Iran at scale 1: 1 000 000. The distribution of major anticlines is shown. Master thrust faults subdivide the ZFTB into different zones. The Dezful Embayment, with numerous oil fields, is bounded by the Balarud and Kazerun transfer zones to the NW and SE, respectively. The N–S- and NE–SW-trending palaeohighs are orthogonal to oblique to the main NW–SE trend of the ZFTB. The location of section B–B′ is also shown. (**B**) Cross-section through the Abadan Plain and the Dezful Embayment along line B–B′, including data from recent seismic profiles and wells. Note the thrust-related structures in the Dezful Embayment and gentle flexures of the Abadan Plain.

The ZFTB is subdivided into the Lurestan, Izeh and Fars zones, which are separated by orogen-oblique transfer structures (Figs 1B and 2A). Towards the foreland, there are two regional saddles (Berberian 1995) or syntaxes (Talbot & Alavi 1996), the ‘Dezful’ (in Iran) and the ‘Kirkuk’ (in Iraq) embayments. These embayments are younger than the Upper Oligocene–Lower Miocene Asmari Formation (Fig. 3). They represent subsiding sedimentary basins and depocentres of Mid-Miocene to Recent age characterized by molasses-type deposits. Subsidence is related to the developing foredeep of the ZFTB.

Henson (1951) proposed four N–S (Arabian Trend), NE–SW, NW–SE and E–W (Figs 1A and 1B) structural trends or fault populations in the Arabian Shield or Platform region, all involving the Precambrian basement (Al-Husseini 2000; Zeigler 2001; Strohmenger *et al.* 2003). Fault-related relief is demonstrated by the Early Cambrian Hormuz Salt (Ala 1974; Brasier, *et al.* 2000), deposited in troughs (Edgell 1996). Salt may have played a role in development of N–S Arabian-type anticlines in the cover section in the form of salt diapirism, salt-wall structures and even salt-cored domes (Al-Husseini 2000). Some of the deep structures were reactivated during the Neotethyan seafloor spreading phase. For example, the Diba Fault in the southeast of ZFTB (DF in Fig. 1B) acted as a transform fault during Neotethyan seafloor spreading (Sharland *et al.* 2001). Another phase of rejuvenation of Arabian-type structures is documented by the Upper Cretaceous sedimentary succession (Motiei 1995). It shows stratigraphic thinning onto basement-cored horsts and fault blocks, as well as erosional removal from some highs (Morris 1977; Koop & Stoneley 1982; Alsharhan & Nairn 1997; Hessami *et al.* 2001; Bahroudi & Talbot 2003; Sherkati & Letouzey 2004; Sepehr & Cosgrove 2004).

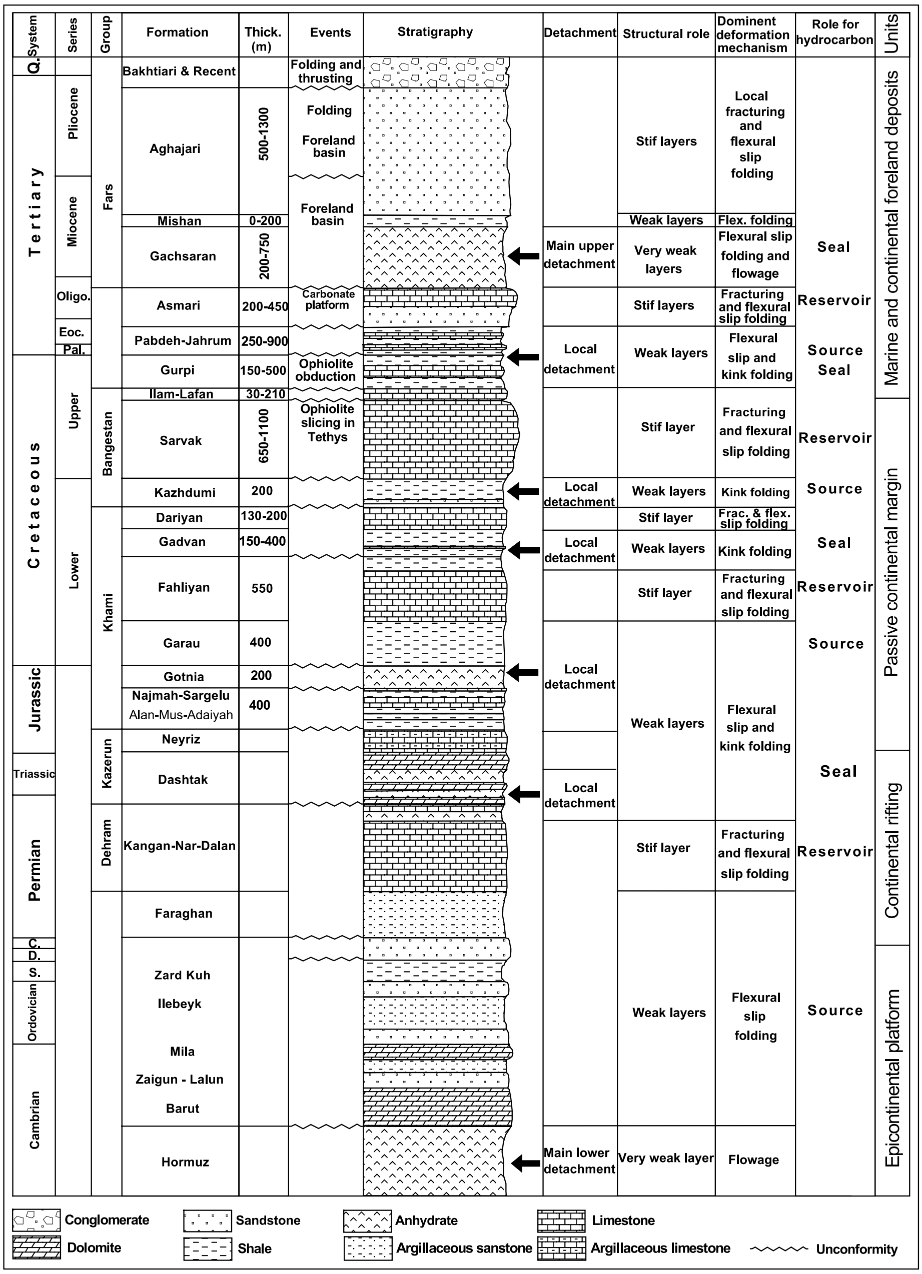

Fig. 3. Simplified stratigraphy of the area depicting the major lithological successions and main tectonic events in the Dezful Embayment and the Abadan Plain. The stratigraphic column is modified from Motiei (1993) and Alavi (2004), based on well data. Mechano-stratigraphy, detachments and influence on the hydrocarbon system are outlined.

Four main tectonic events of depositional significance are recognized in the region (Fig. 3), as summarized in Alavi (2004). Marine and non-marine sedimentary rocks were deposited during the uppermost Neoproterozoic to possibly Devonian. These rocks are overlain unconformably by the platform succession of Permian to Triassic age (Szabo & Kheradpir 1978), which are related to continental rifting (Berberian 1995; Sherkati & Letouzey 2004; Sepehr & Cosgrove 2004). The lowermost Jurassic to upper Turonian sequence was accumulated on a shallow (Neo-Tethyan) continental shelf or passive continental margin associated with seafloor spreading (Berberian 1995). Latest Turonian to Recent marine and continental deposits overlie unconformably the older sequence.

A rapid shift in sedimentation towards more detritic facies marks the passage from passive margin to foreland basin conditions in the region (Molinaro *et al.* 2004). This change is associated with the growth of the ZFTB, which shed syn-orogenic clastic debris (Fig. 3; Upper Miocene to Recent Aghajari and Bakhtiari formations) southwestward from rising thrust sheets into the adjacent subsiding foreland basin. These deposits have subsequently been incorporated in younger thrust sheets and partly recycled into younger basins as deformation proceeded southwestward onto the Arabian Platform.

DATASETS

Knowledge regarding the regional setting forms a base for the detailed data that are required to comprehend the petroleum potential of the Abadan Plain and Dezful Embayment fully. This study is based on the large database of NIOC, including (1) aeromagnetic, (2) gravity, (3) seismic and (4) well data. The total area of the region is about 120 000 km^2, with approximately one third of the area offshore. The aeromagnetic data of SW Iran were gathered in 1969–71 (Kugler 1970; 1973). Main objectives of that survey were the detection of the basement features, depth to basement estimation, and the assessment of throw on possible basement-involved faults (Kugler 1970). The Dezful Embayment and Abadan Plain were also covered by a

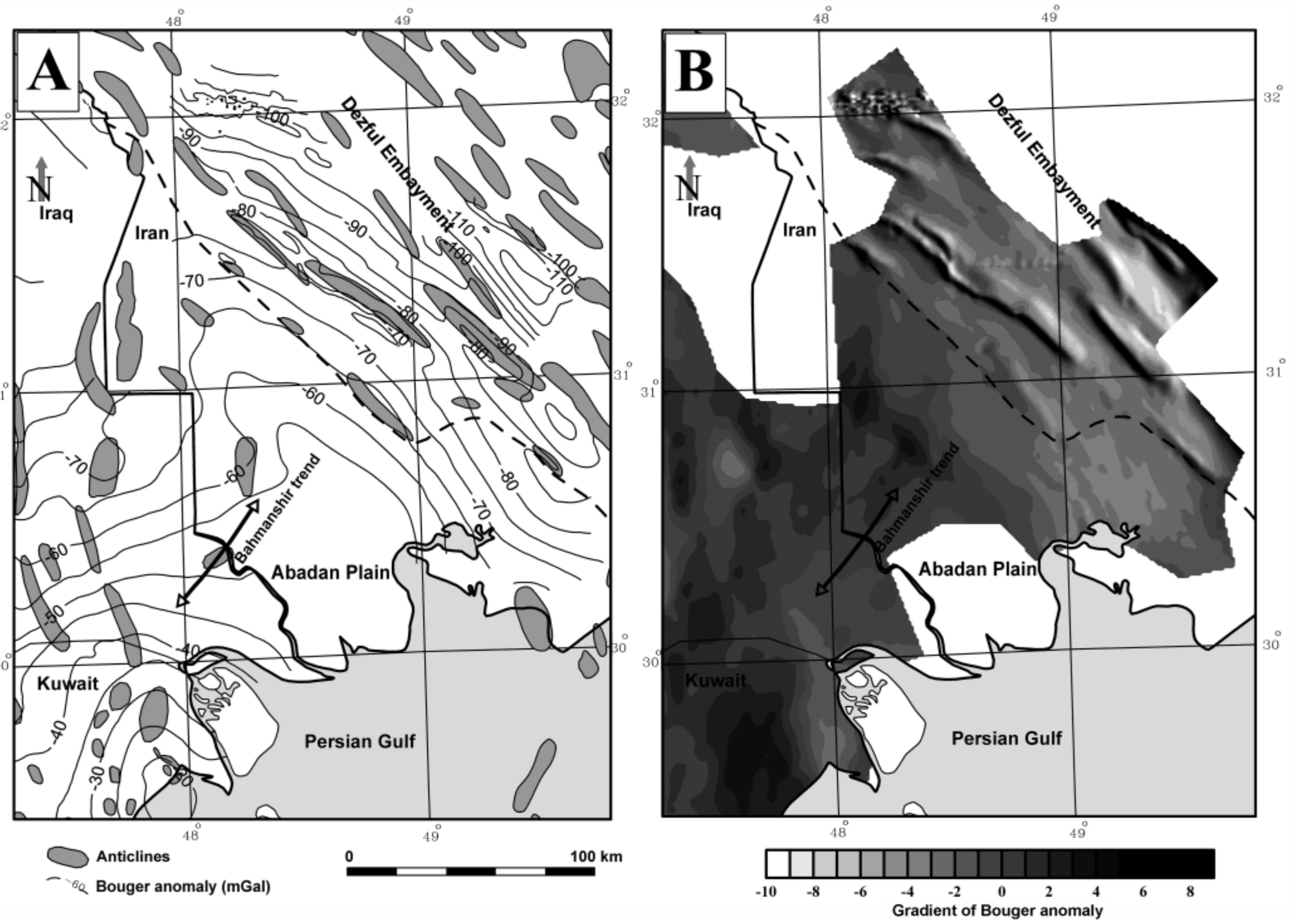

Fig. 4. (**A**) Composite Bouger contour map of SW Iran, SE Iraq and Kuwait, merging datasets of Dehghani & Makris (1983), Abbas (1983) and Warsi (1990). The reduction of Bouger anomaly towards the NE indicates thicker sedimentary cover above basement in the ZFTB foredeep. The N–S-trending anomaly seen in the southwest (Kuwait) corresponds to the Burgan–Azadegan High (Fig. 2). The N–S-trending anomalies deflect to NW–SE trends under the Abadan Plain. The NW–SE anomalies coincide with the main structural trend of the ZFTB. The dashed line is the proposed boundary between the N–S and the NW–SE major trends, consistent with the boundary between the Dezful Embayment and the Abadan Plain. (**B**) East gradient filtered Bouger anomaly map. The N–S-trending anomaly in the southwest (Kuwait) can be seen to grade into the NE–SW-trending anomalies under the Abadan Plain.

gravity survey in the late 1940s and 1950s. However, there is a gap in this gravity dataset along the western part of the Abadan Plain (swamp area along the Iran–Iraq border). Moreover, a regional gravity survey was conducted in Iran during 1977–1978 (Dehghani & Makris 1983). As a result, Abbas (1983) and Warsi (1990) published the gravity Bouger anomaly maps of Iraq and Kuwait, respectively. In this contribution, the datasets from Iran, Iraq and Kuwait have been combined.

Active exploration of the Abadan Plain and Dezful Embayment regions started with seismic acquisition in the late 1950s and the 1960s. The initial surveys were very sparse reconnaissance low-fold 2D seismic profiles, which were acquired both in onshore and offshore regions. In the 1970s, new 2D seismic surveys were undertaken in the northern part of the study area. During the last 10 years, NIOC has acquired 2D and 3D seismic surveys detailing the Dezful Embayment and Abadan Plain. By the end of the last century, the entire study area was covered seismically, with *c.* 100 000 km and *c.* 9000 km^2 of 2D and 3D seismic data, respectively. The quality of the recently acquired seismic data is good (high signal to noise ratio).

More than 150 exploration wells, with average depth of 4000 m, have been drilled in the anticlines of the study area. The geological markers and electrical log data from these wells have been used in the seismic interpretation. As a result of the recent seismic exploration, several wells have been drilled in the Dezful Embayment and the Abadan Plain, leading to major oil discoveries.

REGIONAL MAGNETIC AND GRAVITY CHARACTERISTICS

A composite Bouger anomaly map of Kuwait, SE Iraq and SW Iran shows the predominant reduction of Bouger anomaly towards the northeast, which indicates thicker sedimentary cover above the basement in the region of the ZFTB (Fig. 4A). Another major feature is the N–S-trending anomaly in the southwest (Kuwait). In general, the N–S-trending anomaly changes to NW–SE trends under the Abadan Plain and the Dezful Embayment. The NW–SE-trending anomalies correspond to the ZFTB structures. Based on these major patterns, the boundary between the Dezful Embayment and the Abadan Plain (dashed line, Fig. 4A) can be outlined.

The east gradient, filtered Bouger map (Fig. 4B) shows distinctive differences between the Dezful Embayment and the Abadan Plain. The NW–SE-trending anomalies of the Dezful Embayment signify the anticlines. In the Abadan Plain, a large NW–SE anomaly trend is dominant (Fig. 4). However, in the

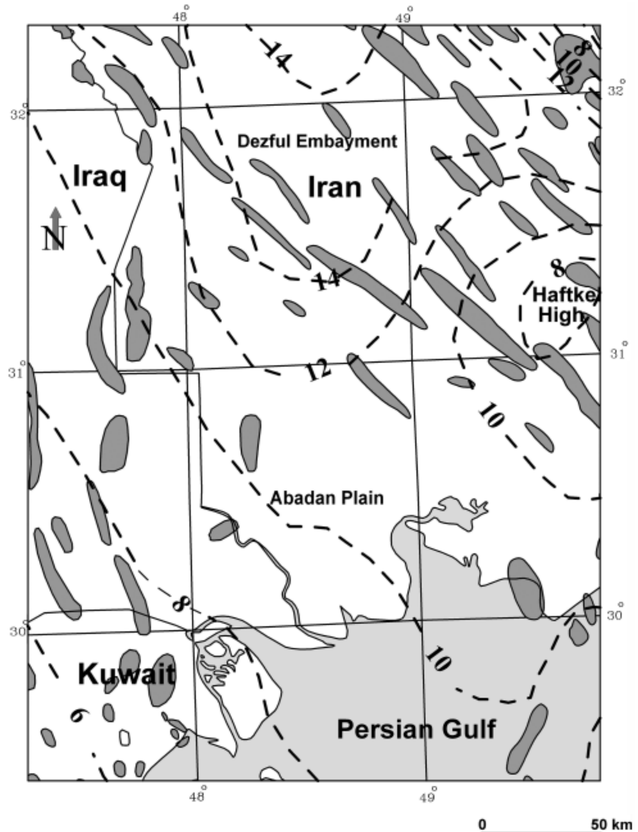

Fig. 5. Depth to basement from mean sea-level (in km), derived from magnetic data (Morris 1977). The basement surface does not show major topographic variations under the Dezful Embayment.

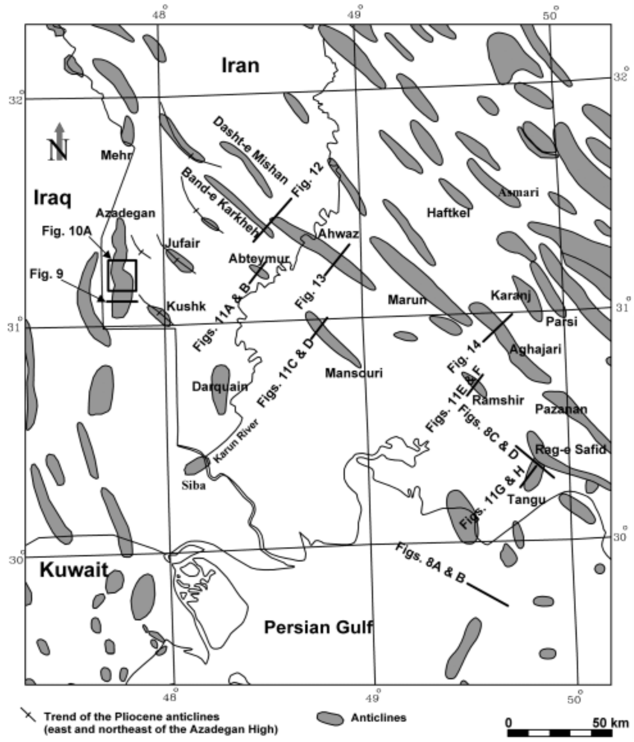

Fig. 6. Structural map of the Dezful Embayment and the Abadan Plain with locality names. Major anticlines appear as elongated domes. The locations of seismic profiles discussed in the paper are outlined.

SW Abadan Plain the regional N–S Arabian trend re-orientates into NE–SW-trending anomalies.

Two depth-to-basement maps based on magnetic data have been published (Fig. 5) (Morris 1977). These maps do not show the distinctive boundary between the Dezful Embayment and the Abadan Plain as seen in the Bouger maps (Fig. 4). Therefore, the style of deformation in the sedimentary cover is the key factor separating the Abadan Plain and the Dezful Embayment. Basement depth decreases towards the southwest and reaches the surface in the most southwesterly parts of the Arabian Shield (Figs 1B, C). In contrast, the basement in the Dezful Embayment is deep, with an estimated maximum of 16 km (Fig. 5). Further northeast, the depth reduces to less than 10 km (Izeh Zone, Fig. 2), which, in most cases, is thought to be related to Late Tertiary, Zagros-related basement-involved thrusting. However, the Haftkel High (Motiei 1995), with a depth to basement of 8 km (Fig. 5), can be explained by Cretaceous, steep faulting.

DEEPLY ROOTED STRUCTURES

The Abadan Plain is characterized by three main, deep-seated trends (Fig. 6): NE–SW, N–S and NW–SE. Many associated structures to these trends have been ascribed to forced folding, related either directly or indirectly to the reactivation of basement-rooted normal faults (Satarzadeh *et al.* 2000). The most prominent NE–SW structure is the regional Hendijan High (Fig. 2A) which, in the southwest, hosts several Iranian and Saudi Arabian oil fields. The high extends northeastwards to the ZFTB and possibly connects to the Izeh Fault in the north. The NE–SW trend is also detectable in the depth map of the Upper Eocene–Lower Miocene Asmari Formation (Fig. 7). A seismic line that crosses the Hendijan High orthogonally (Fig. 8) shows that the well-expressed anticline is almost symmetrical. Onlapping and draping uppermost Cretaceous units record the main folding activity up to the Upper Cretaceous, whereas Cenomanian, Turonian and Santonian rocks were eroded from the crest. Their related reflectors are truncated against the fold-flanking unconformity surface. Onlapping units above the unconformity surface along both flanks represent marine transgressional units. Gentle folding of Upper Cretaceous and Tertiary reflectors indicates that the Hendijan High experienced another growth phase during the Tertiary, seen by layers that are onlapping and/or thinning towards the crest. Part of the thickness variation and onlap features in the Tertiary succession may also be related to differential compaction. In this case, growth of the underlying structure would not be required (e.g. Carminati & Santantonio 2005).

The NE–SW-trending Bahmanshir dome is seen in the gravity map (Fig. 4). It appears as a gentle and broad anticline in Cretaceous and deeper horizons; the Iraqi Siba structure represents the continuation of the dome (Fig. 6). It seems that the Bahmanshir dome terminates in the major, NE–SW-trending Wadi Al Batin lineament (Fig. 1B), which is a remarkably linear, steep-sided palaeo-valley. This feature is 2–10 km wide and traceable for more than 300 km, from the Mesopotamian Foredeep Basin into Saudi Arabia (Carman 1996).

Arabian, N–S-trending, basement-involved horst systems have been named differently, according to their geographical location, such as Burgan High or Arch (Yousif & Nouman 1997; Al-Fares *et al.* 1998), Kuwait High or Arch (Warsi 1990;

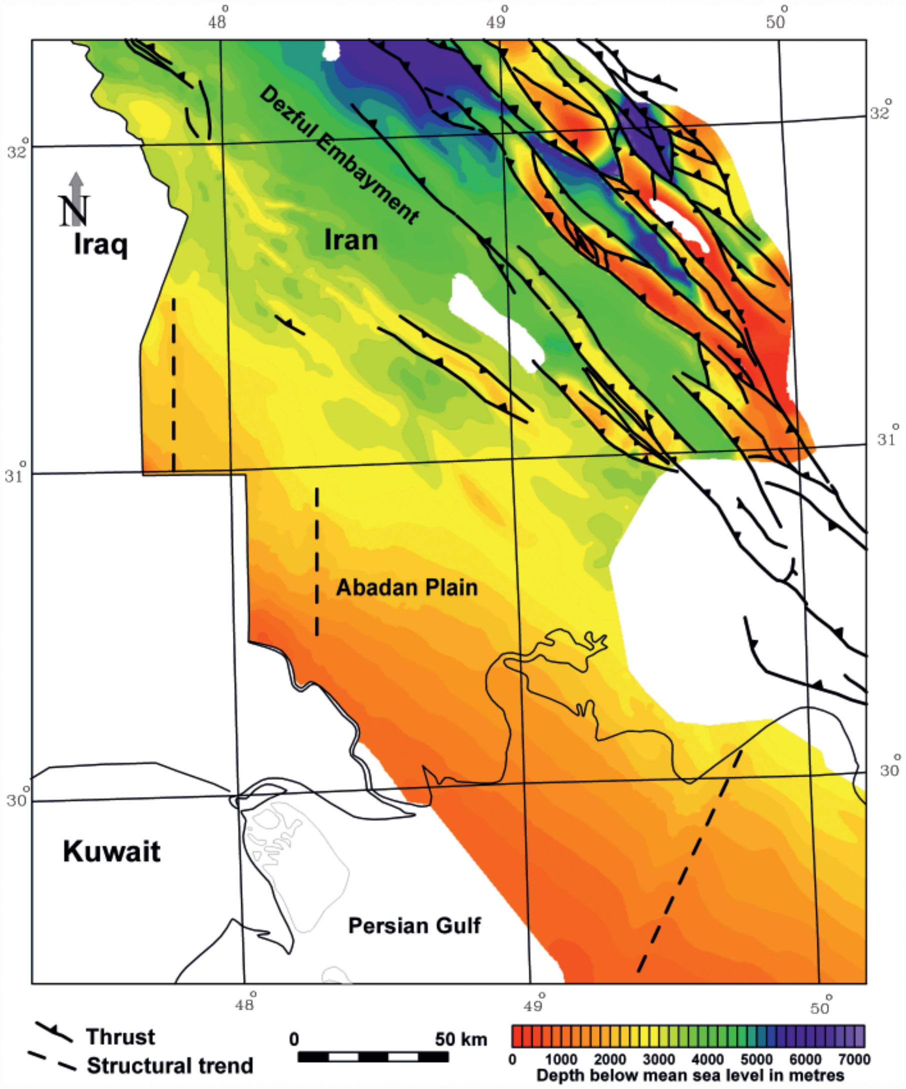

Fig. 7. Depth contour map of the top Upper Eocene to Lower Miocene Asmari Formation. The dominant trend of the structures at the Asmari level in the Dezful Embayment is NW–SE, whereas N–S and NE–SW trends are detectable in the Abadan Plain and the Iranian offshore region (dashed lines). The depth of the Asmari Formation exceeds 7 km below mean sea-level in the north Dezful depocentre, whereas it is elevated above sea-level by folding and thrusting in the northeast and east of the Dezful Embayment. The depth to the Asmari Formation climbs towards the southwest, in accordance with the reduction of depth to basement (Fig. 5).

Carman 1996; Yousif & Nouman 1997), Khurais–Burgan Anticline (Al-Husseini 2000), Basrah High, or Zubair High in Iraq. Several oil fields are located along this regional trend in Saudi Arabia, Kuwait and Iraq. In SW Iran, the N–S trend can be identified both in the Abadan Plain and in the Dezful Embayment. The most prominent N–S structures of the Abadan Plain are the Darquain and Azadegan anticlines and the smaller Mehr Anticline (Fig. 6). The Darquain dome is a broad and gentle anticline, which has four-way structural closure in the Jurassic and Cretaceous strata. The same N–S trend is apparent at shallower levels; however, in this case, without a structural closure (e.g. Fig. 7). The Azadegan dome is a complex horst. Seismic data of the Azadegan structure show steep faulting in the core of the anticline, with faults that die up-section in the Upper Jurassic Gotnia Formation (Fig. 9). Drill-hole and seismic data from the Azadegan and Darquain anticlines demonstrate unconformities and erosional surfaces due to uplifting of basement-cored horsts. For example, incised channels in the top Cenomanian–Turonian Sarvak Formation indicate erosion of the anticline crest in the Upper Cretaceous (Fig. 10).

Examples of NW–SE-trending, deep-seated structures include the Kushk and the Jufair anticlines, of which the former extends to Iraq (Fig. 6). The Kushk anticline is cored by a steep fault zone along its crest.

ZAGROS FOLD–THRUST BELT (ZFTB) STRUCTURES

The ZFTB and foreland reveal a structural style and architecture that have much in common with other fold–thrust belts of the world, such as the Cordilleran thrust belt and Spitsbergen fold–thrust belt (e.g. Royse 1993; Bergh *et al.* 1997). Characteristic features include foreland-directed, southwestward younging of deformation that relates to the maintenance of the southwestward-tapering shape of the ZFTB (Talbot & Alavi 1996). Thrusts of the ZFTB have a ramp and flat geometry (Fig. 2B), where flats occur in weak layers such as the Early Cambrian Hormuz Salt, the Triassic Dashtak evaporate and the Mid Miocene Gachsaran evaporite and shale. Ramp thrusts form in rocks that are relatively competent, such as the Upper Cretaceous Sarvak Formation carbonates (Fig. 3). The geometry of the ZFTB and the evolving foreland basin is controlled by at least three different structural effects: (1) the Tertiary reactivation and growth of the deeply rooted anticlines; (2) buttressing of thrust sheets against deep-seated highs; and (3) lateral changes in the mechanical nature of basal décollements (Talbot & Alavi 1996; Bahroudi & Koyi 2003; 2004).

The ZFTB and foredeep show a general NW–SE structural trend. Towards the northeastern hinterland, thrusts bound Mesozoic and Palaeogene units that are folded into SW-verging

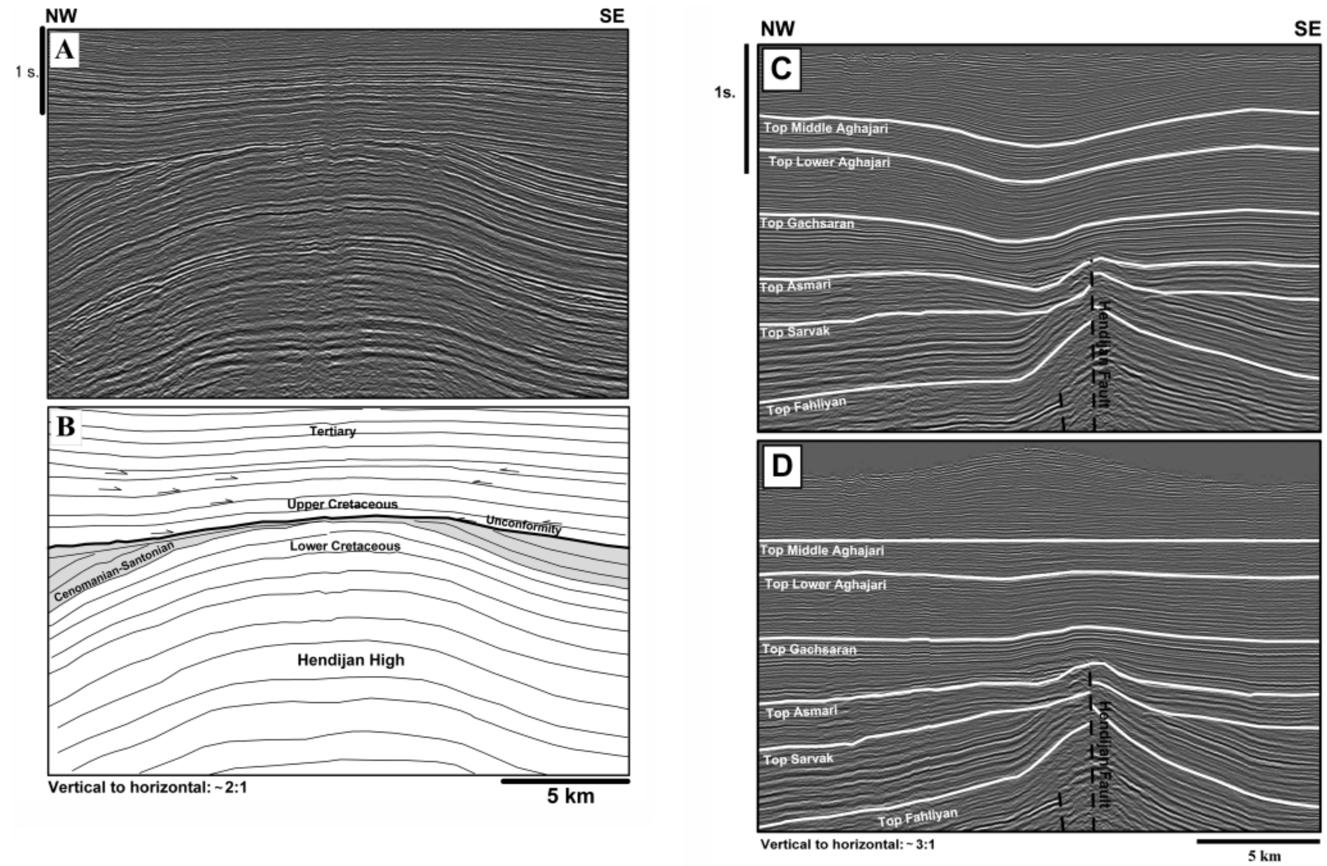

Fig. 8. (**A**) Time-migrated seismic profile across the Hendijan High. See Figure 6 for location. (**B**) Geological interpretation of the seismic profile, showing truncated reflectors in particular. The distinctive Upper Cretaceous unconformity surfaces reflect the sequential activity of the Hendijan High during the Upper Cretaceous. The Cenomanian to Santonian strata were deposited in basins on both sides of the High, whereas there was non-deposition or erosion on the crest. The onlapping syn-tectonic sediments on the northwestern and southeastern flanks of the Hendijan High correspond to the reactivation of the Hendijan High in the Early Tertiary. (**C**) Migrated seismic section crossing the Tangu Anticline (Hendijan High). See Figure 6 for location. (**D**) Profile A flattened at the top Middle Aghajari Formation. Note the thickness variations through the Hendijan High. Thinning of the Lower Cretaceous Fahliyan to Upper Pliocene Aghajari deposits corresponds to the fault activity and uplift of the Hendijan High during the Cretaceous and Tertiary. Thickening of the upper Aghajari represents onset of the Zagros movements which suppress the Hendijan High by overload of the upper Aghajari to Recent deposits.

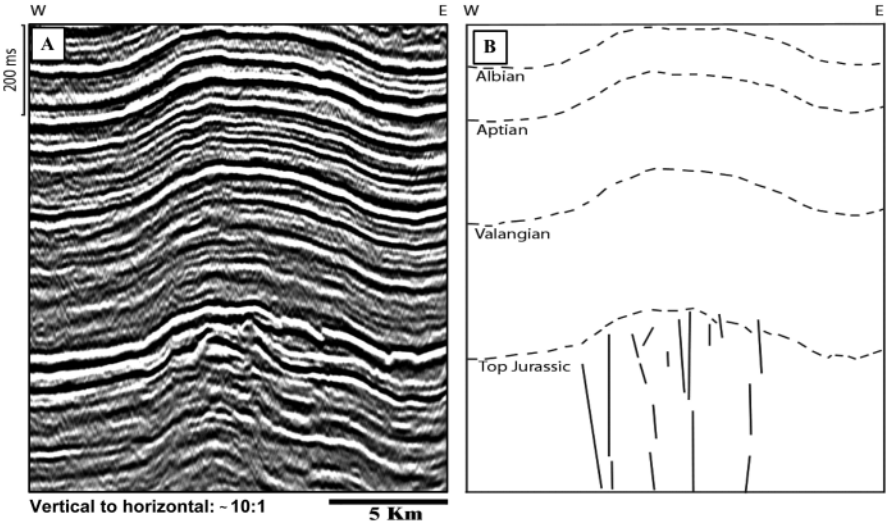

Fig. 9. Seismic profile across the Azadegan High, showing a steep fault system in the Jurassic and underlying sedimentary rocks. The onlapping reflectors, especially on the western flank, and thinning of the layers above the crest, indicate uplift of the Azadegan High during the Upper Cretaceous. See Figure 6 for location. (**B**) Geological interpretation of the Azadegan High. Note that the steep faults die up-section.

hanging-wall anticline–syncline pairs (Fig. 2B). Piggy-back basins are located between major thrusts. Southwestward (i.e. in the Dezful Embayment), thrust displacements gradually decline and the main structures become open fault-propagation folds above blind thrusts. These folds are also partly expressed in extensive Miocene to Recent foreland deposits. The transition to the foreland basin is delineated by very gentle detachment folds of the Abadan Plain.

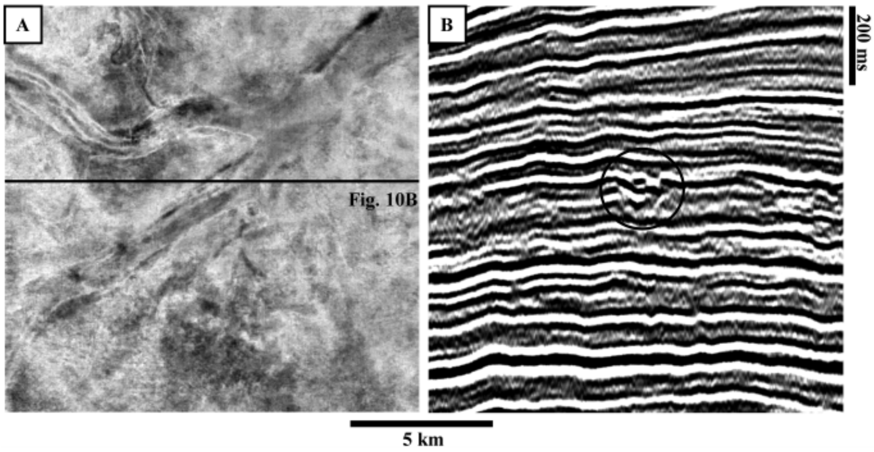

Fig. 10. (**A**) Root mean square volumetric seismic amplitude attribute map, within 30 ms of the upper Turonian sedimentary rocks. The map indicates incised valleys filled by channel-type sediments. See Figure 6 for location. (**B**) Seismic profile through the Azadegan High, showing the channel-type reflector pattern above the Turonian strata. The incised channels reflect the main activity of the Azadegan High which led to the post-Turonian sea-level lowstand.

The ZFTB anticlines of the region have been the main exploration target. Their style is generally found to be a hybrid between detachment folding (Mitra 2003) and fault-propagation folding (Suppe & Medwedeff 1990). However, there is a complete spectrum between buckle folds and fault-related folds (Dixon & Liu 1992). Salt structures (disharmonic folding, flowage and diapirism) are also reported in southeastern parts of the ZFTB (Berberian 1995). The following sections describe the typical structures of the ZFTB in a SW–NE direction – from the frontal structures of the ZFTB of the Abadan Plain into the Dezful Embayment.

Frontal structures of the ZFTB

The Mid-Miocene anhydrate, salt and shale of the Gachsaran Formation act as important detachment horizons in the southwestern region of the ZFTB (Fig. 11). Of significance is that the thickness of the Gachsaran Formation reduces steadily towards the southwest and it changes laterally to a more competent unit in the Abadan Plain. Therefore, the Gachsaran Formation is not acting as a well-developed detachment horizon in the Abadan Plain. However, few observations confirming thrusting in this otherwise regional detachment level may also be due to lower strain in the frontal ZFTB, compared with more extensive shortening in the Dezful Embayment.

There are some examples of local thickening of the Gachsaran Formation in the southwestern flank of Zagros-type folds in the Dezful Embayment. For example, the thickness of this unit is increased by what are probably small thrusts in the southwestern limb of the Abteymur Anticline (Figs 11A, B). The Abteymur Anticline is a gentle NW–SE-trending structure located near the Neogene deformation front of the ZFTB (Fig. 6). Activity is mirrored in the syn-tectonic Aghajari Formation, suggesting a Pliocene age for commencement of the main folding stage of the anticline. The presence of a thrust fault in the core of the anticline is inferred and is consistent with a detachment folding model that roots in a Jurassic detachment level in the Sargelu and Gotnia formations (Fig. 3).

The Mansouri Anticline (Fig. 6) is another gentle, NW–SE-trending structure along the southwestern margin of the ZFTB (Figs 11C, D). In this case, the Gachsaran Formation detachment is expressed better when compared with that seen in the Abteymur Anticline. The amplitude of the Mansouri Anticline is clearly higher at shallower levels; however, a gentle anticline can be seen down to the Cretaceous level, suggesting that the detachment itself is slightly folded. One possible cause for this two-level detachment fold pattern is that the frontal thrust of the ZFTB abuts a deeper-seated anticline. This forces thrust imbrication within the detachment, and detachment folding of overlying units. The considerable lateral thickness variation of the Upper Miocene to Pliocene Aghajari growth strata indicates that the Mansouri Anticline is another Neogene structure.

Well-developed folds exist, such as the Ramshir Anticline (Figs 6 and 11E, F). This anticline has steeper flanks than the Abteymur and Mansouri structures and is classified as an open fold. Again, the Gachsaran Formation shows thickness variations. In this case, the forelimb of the anticline reveals thickening, probably from NE-directed out-of-the-syncline thrusting or, alternatively, caused by a rotated imbricate fan.

Of special interest is the interference between deep-seated highs/anticlines and the frontal part of the ZFTB. This is illustrated in Figures 11G and H, where a deeply rooted anticline appears at Cretaceous level (Tangu Anticline, Fig. 6). The structure is modified by younger ZFTB thrusting in that the anticline appears slightly decapitated, and there is no sign of the shallow-level folding that is commonly seen above such deep-seated anticlines, as exemplified in Figure 11D. In this case as well, a series of open flexures above the Mid-Miocene reflectors represent detachment folding above the Gachsaran Formation detachment.

ZFTB structures in the Dezful Embayment

In the Dezful Embayment, fold–thrust belt structures are expressed clearly both in subsurface and surface data. A more extensive stratigraphic section is involved compared with the Abadan Plain, as deeper, weak lithologies are utilized as detachments. Important detachment levels include the Hormuz Salt, and the Dashtak, Sargelu–Gotnia, Garau, Kazhdumi, Gurpi, Pabdeh and the Gachsaran formations (Fig. 3). The Dezful Embayment contains many anticlines (Figs 12 and 13), of which most relate to deep detachment thrusting. Some could also be caused by basement-rooted, steep faulting. These two contrasting mechanisms are not always possible to distinguish, due to the depth of the structure in question. The well-expressed, deep-rooted folds are open to gentle and upright, with an overall elliptical shape in map view. This fold shape is probably related to strong, thick limestones, such as the Upper Cretaceous Sarvak Formation.

Three sub-parallel, NW–SE-trending anticlines (Fig. 6) are shown in a migrated seismic profile (Fig. 12). These anticlines are gentle, with rounded shape in cross-section. They also affect the Gachsaran Formation, which represents a main, upper detachment horizon. This is illustrated by distinct differences in the style of folds above and below this unit. Internal wedge geometries in the post-Gachsaran growth strata are related to

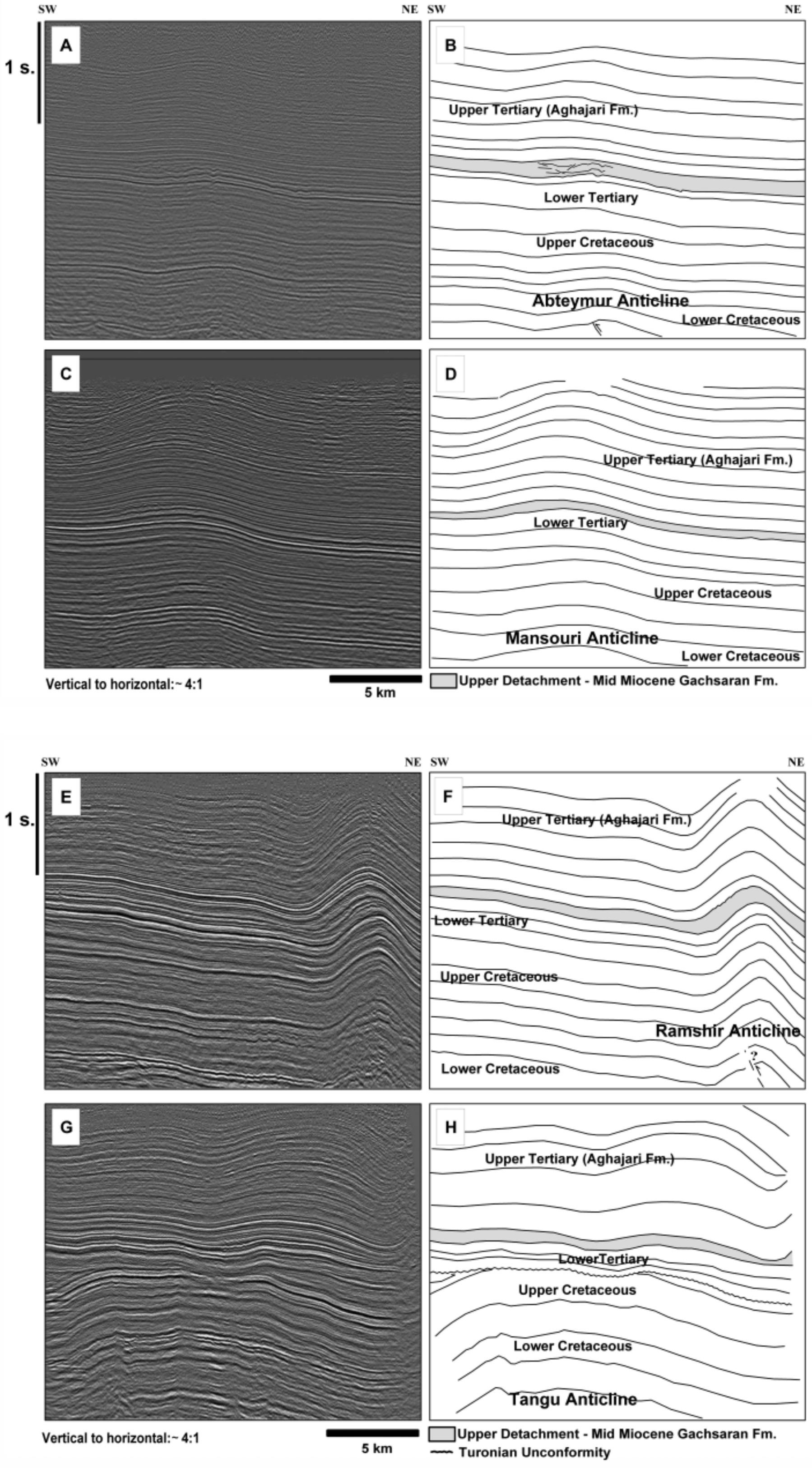

Fig. 11. Four seismic sections and their interpretation, from the Abadan Plain–Dezful Embayment transition zone, crossing the frontal structures of the Neogene ZFTB. Note local thickening of the Mid Miocene Gachsaran Formation, indicating it as a local décollement layer. See Figure 6 for location of the sections. (**A**) NE–SW seismic section and (**B**) interpretation across the Abteymur structure. (**C**) NE–SW seismic profile and (**D**) interpretation through the Mansouri Anticline. The Upper Miocene to Pliocene Aghajari growth strata presents the Mansouri structure as a young anticline, which was active during the later stages of the Zagros Orogeny. (**E**) Seismic section and (**F**) interpretation across the Ramshir Anticline. (**G**) NE–SW seismic profile and (**H**) interpretation crossing the Tangu Anticline. The Tangu Anticline of the Hendijan High (Fig. 2A) was formed during Upper Cretaceous movements and reactivated by the Zagros-type thrusting.

growth of detachment or fault-propagation folds in the syntectonic deposits, where associated uplift and subsidence have created unconformities and onlap structures. Such features, when identified, suggest that the main folding phase was in the Late Pliocene.

In some seismic sections, thrust faults can be identified in the southwestern limb of the deeply rooted anticlines. These faults die up-section, or sole out in the Mid-Miocene Gachsaran Formation. Detailed analyses of larger anticlines reveal both steeper reverse faults (Figs 12 and 13) and low-angle thrusts

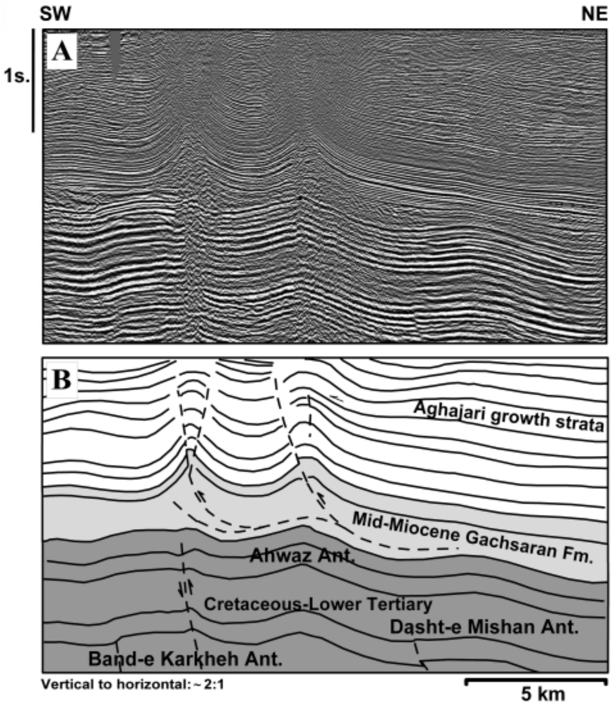

Fig. 12. (**A**) Migrated seismic section crossing three sub-parallel, NW–SE-trending Zagros-type structures. See Figure 6 for location. (**B**) Interpretation of profile A. Note the anticlines beneath the Gachsaran detachment – open to gentle. In contrast, folds above the detachment have shorter wavelengths. Hence, the Gachsaran Formation separates the shallower thrusts from the deeper folds. The post-Gachsaran growth strata show that the main thrust and fold activity is younger than Miocene.

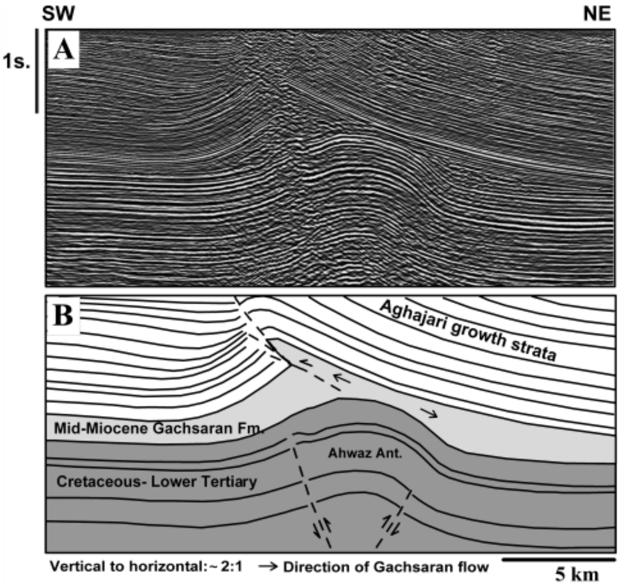

Fig. 13. (**A**) Migrated seismic section and (**B**) interpretation across the Ahwaz Anticline. See Figure 6 for location. Both SW- and NE-directed reverse faults are seen at depth in the Ahwaz Anticline. The shallow, low-angle thrusts root within the Gachsaran Formation. The Ahwaz anticline seems to be truncated by thrusting, suggesting out-of-sequence thrust activity within the Gachsaran Formation detachment. Post-Gachsaran growth strata indicate that deposition in front of the shallow thrusts were synchronous with the thrust movements. This basin probably had a piggy-back status.

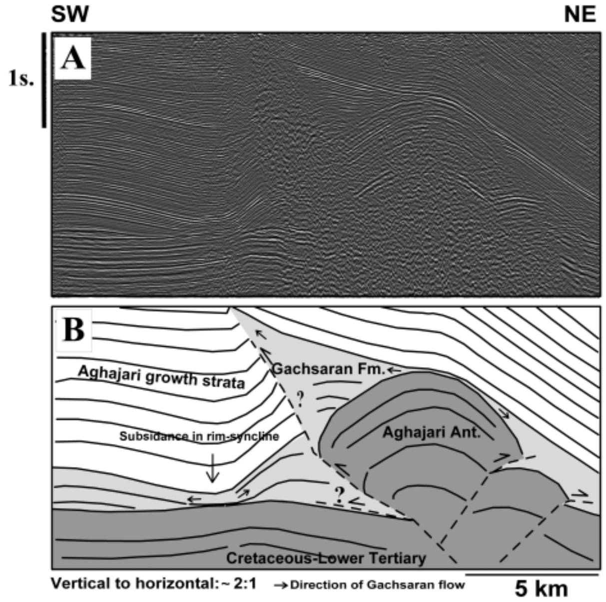

Fig. 14. (**A**) Unmigrated seismic section and (**B**) interpretation through the Aghajari Anticline. The deeply rooted, main thrust in the southwestern flank of the Aghajari Anticline cuts up-section and flattens or branches in the Gachsaran detachment. Back-thrusts cut up from the major fore-thrust. Note decapitation of the anticline at the Gachsaran Formation level, suggesting out-of-sequence thrusting along this detachment. The wedge-shaped reflector pattern in the footwall of the shallow fore-thrust indicates syn-tectonic deposition of the Lower Aghajari strata, dating Gachsaran Formation detachment movements to the Upper Miocene–Lower Pliocene.

(Fig. 14), suggesting that the anticlines formed by several mechanisms. These include: (1) fault-propagation folding as displacements on faults die up-section; (2) fault-bend folding above flat-ramp-flat thrusts; and (3) roof folding above duplexes (Boyer & Elliot 1982). The latter are hinterland-dipping or antiformal stack duplexes, as deeper thrusts ramp up to the Gachsaran Formation detachment. Another characteristic feature is that as thrusts cut up-section towards the Gachsaran Formation detachment, back-thrusts tend to form. This is especially clear in the thick, competent limestones of the Sarvak Formation, which accommodate minor folding before fracturing. The best example is represented by the Aghajari Anticline (Fig. 14), where several back-thrusts cut up from the master thrust into the Gachsaran detachment. In this case, the back-thrusts assist in the formation of the major anticline that characterizes the Mesozoic–Early Tertiary level.

Tight synclines and overturned anticlines are common around the main thrusts but cannot be detected in the seismic sections due to lack of resolution. Indications for this are observed as thickening and thinning of, for example, the incompetent units of the Gachsaran Formation which flow from the crest to the flanks of the Aghajari Anticline (Fig. 14). The Aghajari Formation in the southwestern flank of the Aghajari Anticline is deposited in an active piggy-back basin. Wedge-shaped units suggest that the main folding stage of the Aghajari Anticline started in the Upper Miocene–Lower Pliocene.

Another striking feature of the region is the complex nature of the Gachsaran Formation detachment level. Both in-sequence and out-of-sequence thrusts in syn-tectonic deposits can be seen to cut up from this level. In Figure 13, and also possibly in Figure 14, a thrust fault cuts into the northeast flank of the deeper anticline, and then ramps up-section into

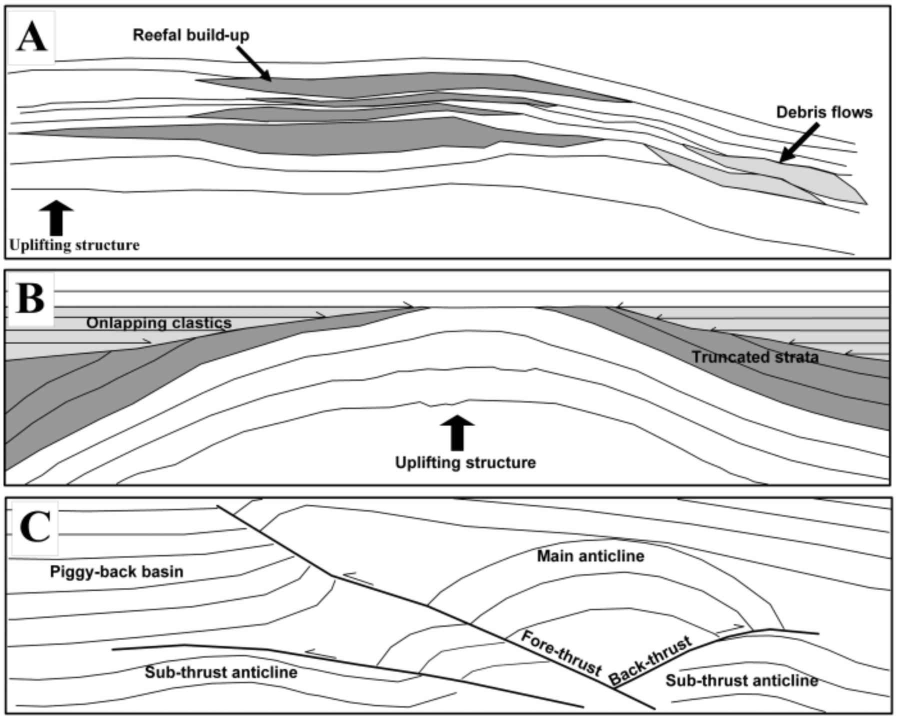

Fig. 15. Untested stratigraphic and structural traps in the Abadan Plain and the Dezful Embayment. (**A**) Model for reefal build-ups with considerable matrix porosity, which were constructed on the crest or flanks of the uplifting Cretaceous highs. Debris flows characterized the flank of the palaeohighs. The debris flows are sandwiched between fine-grained sediments representing possible source rocks and seals. (**B**) Model for truncated strata in the flanks of the palaeohighs, and onlapping clastics along the limbs of the anticlines. (**C**) Key structural traps are shown by the major anticline, whereas challenging structural traps include sub-thrust anticlines and truncated reservoir units below possible sealing thrusts.

the syn-tectonic sediments. Those thrusts are clearly out-of-sequence thrusts, since the overall geometry suggests that the anticlines were developed before thrusting. The deeply rooted folds acted as obstacles for foreland-directed thrust propagation in the Gachsaran Formation. Consequently, late, layer-parallel thrusts were forced to propagate as ramps above the anticlines.

DISCUSSION

In order to comprehend the tectonic development of the Dezful Embayment and Abadan Plain, this discussion begins with the two overall structural styles: deep-seated anticlines and fold–thrust structures. Hydrocarbon discoveries in the province are all located within major anticlinal domes, where fractured carbonates form good reservoirs. This knowledge is built upon when exploited plays and new exploration targets are addressed. The last section considers areas where the two different structural styles interact, resulting in complex structures and associated, challenging petroleum plays.

Deep-seated structures and their petroleum potential

When addressing structural and stratigraphic traps associated with the Arabian-type structures, their temporal development is important. In the Abadan Plain and Dezful Embayment, the deep-seated anticlines have seen several growth stages that enhanced their geometry. The Coniacian is the climax of the tectonic activity in the Kharg–Mish High (Fig. 2A), which coincides with a widespread regional regression. For the Hendijan High, truncated and onlap reflector patterns (Fig. 8) indicate post-Cenomanian non-deposition or erosion of the crest, whereas Turonian sedimentary rocks were deposited in elongated, marginal basins. Similarly, the Azadegan Anticline reveals channel type sedimentation (subaerial exposure) during the Upper Cretaceous (Figs 8–10). In summery, erosional–depositional patterns of the highs evidence widespread shallowing and possibly supratidal depositional environments due to deep-seated, possibly basement-rooted epiorogenic movements. The most obvious activity started in the Upper Cretaceous.

The Upper Eocene is suggested as the end of uplift of the Hendijan and Kharg–Mish highs. However, there is evidence for continued activity to the present. For example, the depth map of the top of the Upper Eocene to Lower Miocene Asmari Formation (Fig. 7) shows the effects of the Hendijan, Azadegan and Darquain highs. In addition, the NE–SW-trending, deeply rooted, steep faults penetrate into Late Tertiary units above the Hendijan High. Both observations are reflected in isopachs of the younger Tertiary units showing thinning parallel to the axes of the highs. It is, therefore, concluded that the N–S- and NE–SW-trending structures were reactivated by the onset of the Zagros Orogeny. They are still active, as suggested by thickness variations of Pliocene units along the Azadegan Anticline. Another example of ongoing deeply rooted folding is represented by the Darquain structure, which causes surface uplift and thereby deflection of the Karun River (Fig. 6).

As mentioned, fractured carbonates of the major anticlines form good reservoirs. Additional, new exploration targets around the major anticlines include the Cretaceous carbonates that were deposited in a mud-rich, widespread intra-shelf environment with high sensitivity to water depth variations. The palaeohighs of Arabian-type structures were active during the sedimentation of carbonates, and vertical movements along faults or uplifting of the structures affected the topography of the basin. Therefore, a significant reservoir potential exists in reefal build-ups with considerable matrix porosity, which was constructed over the uplifting structures in tropical marine conditions (Handford & Loucks 1993) (Fig. 15A). Debris flows on the flank of the palaeohighs are other potential stratigraphic traps (Fig. 15B). These units are sandwiched between fine-grained sedimentary rocks. Wave-dominated delta systems (e.g. Burgan delta equivalent to the Kazhdumi Formation, Fig. 3) were established in the Lower Cretaceous, when the palaeohighs were their erosional sources (Figs 8 and 10). Examples for such plays include the onlapping layers on the flanks of the Hendijan (Fig. 8) and Kharg–Mish highs. The onlap features probably represent coarse-grained transgressive clastic units. In other words, the old, pre-Zagros Orogeny structures play an important role in the formation of stratigraphic traps, while the Cretaceous tectonic setting controlled the initial geometry of the shallow-marine, carbonate-dominated basins.

Fold–thrust belt structures and their petroleum potential

The regular spacing of thrusts in, for example, the Idaho–Wyoming–Utah thrust belt developed over a featureless basement surface (Dixon 1982; Hatcher 2004). The relatively regularly spaced Hormuz Salt-rooted thrusts in the northern part of the Dezful Embayment suggest that there is a similar, relatively featureless basement there or, more likely – based on geophysical mapping (Figs 4 and 5) – that the Hormuz Salt décollement to a certain degree detaches deformation from underlying irregularities (Blanc *et al.* 2003). The Dezful Embayment is bound by two distinct transfer zones, the Balarud and Kazerun transform faults (Fig. 2A). Outside the embayment, the fold–thrust belt has been exhumed to deeper levels, whereas the embayment has been subsiding. The latter is illustrated by the thick syn-tectonic sedimentary sequence with more than 4000 m of clastic rocks. Talbot & Alavi (1996) argued that this regional pattern relates to the distribution of the Early Cambrian Hormuz Salt, concluding that regions without salt experienced significant thickening and thereby uplift in a steep fold–thrust wedge. Contrary, regions soled by salt experienced extensive foreland propagation in a gentle fold–thrust belt wedge. In analogue experiments, Bahroudi & Koyi (2003) and McClay *et al.* (2004) tested the possible control of salt on Zagros shortening domains. The latter paper also addressed the effect of oblique convergence, and the influence of fault-bounded, deep-seated basement highs and lows. They concluded that oblique- and strike-slip faults could be formed by reactivation of older basement faults, which has similarities to the deflection of thrusts seen around deep-seated anticlines (see below). Alternatively, variable distribution of the Hormuz Salt could aid formation of transport-oblique structures. In any case, the deposition of the molasses-type Mid-Miocene to Recent rocks in the basin of the Dezful Embayment was and is increasing the bulk weight above the basement and adds to the downward warping of this region.

The anticlines of the Dezful Embayment are found to be linear to curved, elongated in map view, and mostly asymmetrical, with steeper southwestern flanks. They have generally been interpreted as detachment folds above the Early Cambrian Hormuz Salt (Colman-Sadd 1978), which have been formed by a combination of flexural-slip and neutral-surface folding (McQuillan 1974; Coleman-Sadd 1978; De Jong 1982; Alsharhan & Nairn 1997). The projection of the concentric folds to depth produces space incompatibilities that require disharmonic folding of ductile layers above detachments (Mitra 1990; McQuarrie 2004). Several detachment levels (Fig. 3) during progressive deformation, as found in the Dezful Embayment, increase geometrical complexity (Sherkati & Letouzey 2004), including hinge and limb accommodation thrusts (Mitra 2002*a*) and duplexes (Boyer & Elliot 1982). Furthermore, steep to overturned forelimbs in short-wavelength structures (e.g. Aghajari Anticline, Figs 6 and 14) indicate that translation is limited on individual thrusts (Strayer *et al.* 2004), thereby producing fault-propagation folds (McQuarrie 2004) in front of blind thrusts. In some structures, the fore-thrust climbs up to the Gachsaran Formation, where it flattens (Fig. 14). There, fore-thrusts display a curved ramp-flat geometry (Suppe 1985) and the associated fault-propagation fold changes to a transported fault-propagation fold with continued movement of the thrust sheet over the footwall ramp.

Back-thrusts (Mitra 2002*a*, *b*) are common in the Dezful Embayment (Figs 14 and 15). They cut up-section towards the hinterland, and root in fore-thrusts. They originated in areas with high friction to the foreland-directed thrusting, such as (a) on thrust ramps; (b) where there are lateral sedimentary facies changes or (c) where thrust propagation is hampered by, for example, deep-seated structures (see below). An example of facies changes is found in the Upper Cretaceous Sarvak Formation. This is a dominant sequence consisting of a thin-layered pelagic calcareous unit northeast of the Aghajari Anticline. It changes laterally to a massive competent neritic limestone in the Aghajari Anticline. In this light, increased layer-mechanic strength of this unit can explain the local deformation front along the Marun, Aghajari, Pazanan, and Rag-e Safid anticlines (Figs 6 and 14). Other examples of facies changes include the Paleocene to Lower Eocene Pabdeh Formation of basinal marl and shale sediments, which changes laterally to the Jahrum shelf carbonates (Fig. 3). Furthermore, the Albian Burgan Formation of shallow delta clastics in the southwest of the Abadan Plain changes to the Kazhdumi Formation basinal shale in the northeast. The described changes in layer-mechanic resistance to fore-thrusting may explain back-thrusting and/or pop-up structures, which typically are seen in the Mid Miocene–Pliocene syn-tectonic rocks (Fig. 12). It is therefore likely that changing layer mechanics as a result of lateral facies changes at least partly controlled the structural style of the region.

Out-of-sequence thrusts (Morley 1988) are documented clearly on the northeast (hinterland) side of deeper folds (Figs 13 and 14) of the Dezful Embayment. This suggests that, first, the fold–thrust belt has experienced phases of instability within the composite fold–thrust taper, as also discussed for other fold–thrust belts (e.g. DeCelles & Mitra 1996; Braathen *et al.* 1999). Secondly, the deeply rooted folds force thrust propagation into the syn-tectonic stratigraphic section (see below). Both the activity of the in-sequence and out-of-sequence thrusts is synchronous with the sedimentation of the Miocene to Recent clastic debris. This is confirmed by convergent reflector patterns in the footwall of the surface-breaching thrusts (e.g. Figs 13 and 14). There, the thick syn-tectonic package of the Upper Miocene to Pliocene Aghajari Formation has an additional, profound effect on structural evolution. This mechanically strong unit is suggested to act as a buttress to translation in a foreland direction (Strayer *et al.* 2004) by decreasing the slip-to-propagation ratio, causing fault-propagation folding.

The main ZFTB anticlines with fractured limestone as a target for hydrocarbon exploration have been exploited for a century. However, the potential of the adjacent sub-thrust structures is still basically untested (Fig. 15C); oil has been proven in such a position in a recent drilling. Such plays include sub-thrust anticlines and truncated reservoir layers below potentially sealing thrusts. These plays are, however, hampered by uncertainties due to poor seismic resolution and low signal to noise ratio, requiring new, precise methods such as long offset seismic data. The syn-tectonic Pliocene clastic wedges around the fault-propagation anticlines, albeit with high porosity, are not considered as reservoir due to a lack of migration paths and top seal.

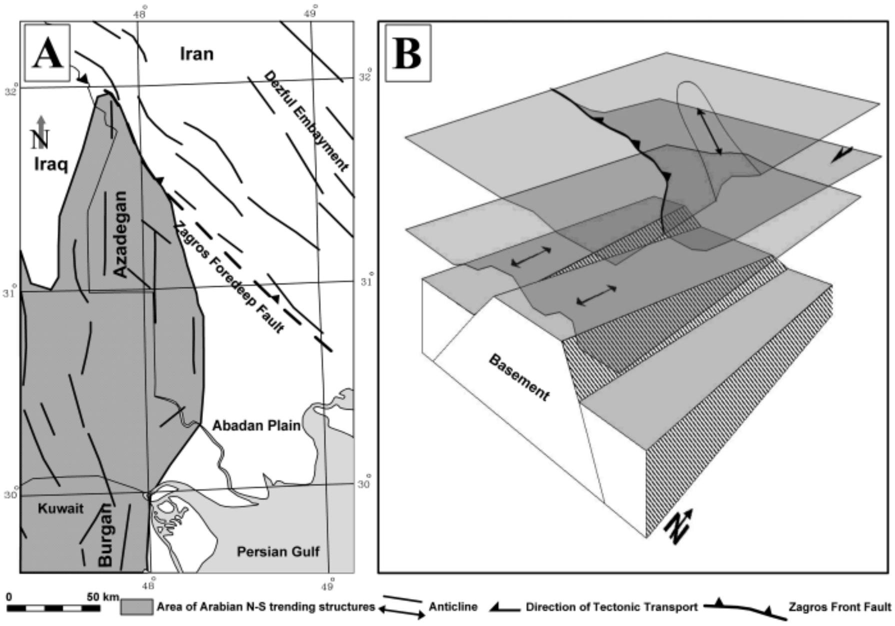

Fig. 16. (**A**) Structural map of the region characterized by Arabian-type, N–S-trending anticlines. They relate to the Burgan–Azadegan High of the Abadan Plain, SE Iraq and Kuwait. (**B**) A conceptual, three-dimensional model illustrating the interaction of the Zagros-type NW–SE-trending structures with the deep-rooted Arabian-type, N–S-trending faults and anticlines. The frontal structures of the Neogene ZFTB are deflected locally in the influence area of the N–S-trending anticlines.

Interaction between deep-seated anticlines and fold–thrust structures

Interaction between ZFTB structures and deep-seated anticlines is similar to that occurring in the frontal Cordilleran fold–thrust belt, which abuts Laramide-style, basement-cored uplifts of the Rocky Mountain foreland to the east (Kulik & Schmidt 1988; Royse 1993). Another example is the West Spitsbergen fold–thrust belt that interacts with folds above basement-involved steep faults towards the foreland (e.g. Bergh *et al.* 1997). Examples of large-scale interaction from the Abadan Plain include the N–S Azadegan structure, where younger shallow anticlines and their related thrusts are deflected from NW–SE to NNW–SSE orientations (Fig. 16). This change in orientation is associated with fore-thrusts that are forced to climb to shallower stratigraphic levels when interfering with the deeper anticlines. Other cases include thickness variations in the Gachsaran Formation that could be explained by thrust buttressing along deep-seated anticlines.

The significant thickness variations seen in the Gachsaran Formation around deep-seated folds can be ascribed to at least three interacting scenarios.

1. Blocking of thrust-propagation in the Gachsaran Formation caused by lateral facies changes in this unit. Relatively abrupt facies changes in Cretaceous to Lower Tertiary units along the borders of the individual deep-seated anticlines have, for example, been reported in Iraq, where layer-mechanical differences trigger a change in structural style (Kassab *et al.* 1987).
2. Thickness variations caused by flow of salt from crest to limbs, as suggested by Sherkati *et al.* (2005).
3. Thrust stacking resulting in localized thickening.

Here, a thrust-tectonic stand is adopted, which explains the thickness changes with thrust stacking and out-of-sequence thrusting, in accordance with the Gachsaran Formation as an extremely weak detachment layer. Applying thrust-tectonic interpretations on the geometries, there are good examples of anticlines that are decapitated by thrusts in the Dezful Embayment (Figs 13 and 14). General thickening of the Gachsaran Formation along the abutting, northeast side of anticlines is consistent with thrust-staking or duplexes. This thickening can be explained by two equally valid scenarios (Fig. 17): (a) thrust buttressing against a pre-existing anticline causes horses to form in a back-stepping sequence of duplex formation; or (b) a raising anticline causes thrust buttressing in a similar back-stepping duplex formation, but with ramp-thrusts and horses showing progressive rotation towards the major anticline. In both cases the duplex will probably be hinterland dipping since thrusts form in an attempt to climb over an obstacle. In other words, they fill the developing syncline, thus reducing thrust

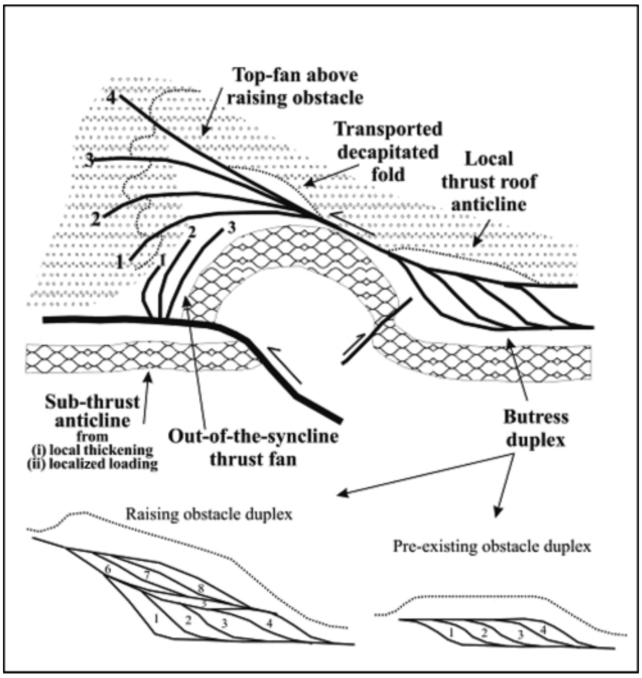

Fig. 17. Structures developed in areas where shallow thrusts interact with deep-seated anticlines. These include buttress duplexes, top imbricate fans and out-of-the-syncline back-thrusts. Possible petroleum targets are hanging-wall anticlines above duplexes, and subordinate anticlines related to the thrust fans. Major plays are the decapitated and displaced part of the large anticline, as well as the deeper anticline.

topography. As commonly seen in fold–thrust belts, duplexes have hanging-wall anticlines. In the case of a raising obstacle, the duplex-related anticline will experience superimposed folding and thereby become enhanced.

Above the crest of the major anticlines, where thrusts ramp in to the syn-tectonic deposits, thickening and thinning of the Gachsaran Formation can be explained in two ways: (a) by out-of-sequence thrusting that decapitates and places shallow parts of the anticlines in a foreland direction; and (b) by an imbricate fan (Fig. 17). A top-fan with variably rotated thrusts can be envisaged if the major anticline is progressively growing and interacting with shallow thrusting. Another implication is that the partly folded imbricate fan adds growth to the fault-propagation fold in the syn-tectonic section, explaining the enhanced fold amplitude at shallow levels.

Thickening of the Gachsaran Formation in the southwestern forelimb of major anticlines can be explained by an out-of-the-syncline thrust fan that has become rotated progressively by superimposed folding (Fig. 17). A similar model has been proposed for the forelimb of major basement-core anticlines in the Rocky Mountain foreland (e.g. Brown 1993). In this light, it is clear that the above discussion is valid both for fold–thrust belt structures developed by two interacting detachment levels, as well as for interaction between deep-seated anticlines and shallower fold–thrust belt structures, as seen in the Abadan Plain and Dezful Embayment.

Petroleum plays unique to areas experiencing interaction of the thrust system and deep-seated anticlines include (Fig. 17) anticlines above buttress-related duplex anticlines and structures related to out-of-sequence thrusting. In the latter case, both the decapitated and forelandward-translated anticline and the deeper, decapitated anticline represent major plays. Smaller folds associated with the top imbricate fan and the out-of-the syncline thrusts represent subordinate targets.

In agreement with the above discussion, petroleum prospects of the ZFTB and the evolving foreland basin are controlled by at least three different structural effects: (1) the Tertiary reactivation and growth of the deeply rooted anticlines; (2) buttressing of thrust sheets against deep-seated highs; and (3) lateral changes in the mechanical nature of décollements (Talbot & Alavi 1996; Bahroudi & Koyi 2003; 2004). Hereto, the success in identifying and producing Iranian oil fields lies in the simplicity of the geological model; drilling the top of an anticline with lateral closure results in a hydrocarbon discovery in almost all cases. However, this strategy may leave smaller field unexploited, even in the vicinity of production infrastructure, thereby in reality reducing the success rate. More advanced geological models will be required in order to increase or even sustain production. This paper has identified several, more challenging hydrocarbon traps that remain untested in SW Iran. They represent the targets of future exploration.

CONCLUSIONS

The following conclusions can be drawn from the presented, extensive dataset from the Dezful Embayment and the Abadan Plain.

1. Deep seated anticlines relate to the Arabian-type, basement-involved structures. These N–S- to NE–SW-trending structures experienced significant Cretaceous activity that may have triggered Hormuz Salt movements.
2. Deep-seated anticlines were, in some cases, slightly rejuvenated during the Zagros Orogeny, either from reactivation of basement-involved faults, or from detachment thrusting in the Hormuz Salt.
3. The basal Hormuz and upper Gachsaran detachments play important roles for the style of the Zagros Fold–Thrust Belt. Several intermediate décollements increase the complexity. The Jurassic Sargelu and Gotnia formations are important intermediate incompetent layers in the Abadan Plain.
4. The Zagros Fold–Thrust Belt interacts with deep-seated anticlines. The latter are decapitated, and the Gachsaran Formation detachment shows thickening by thrust imbrication and possibly duplexes along the obstructing side of the anticlines. Thrusts are also forced upwards into the syn-tectonic clastic section.
5. A wide spectrum of fold styles exists in the Dezful Embayment. Towards the foreland folds are gentle, rounded and upright. They show initial stages of detachment folding. Towards the hinterland, fault-propagation folding and fault-bend folding above stepwise thrusts, and duplexes, are found in stiff limestone.
6. Major anticlines of the Dezful Embayment and the Abadan Plain are proven petroleum traps. New targets include stratigraphic traps such as reefal build-ups, debris flows, truncated sedimentary units and onlapping clastic sequences around deep-seated anticlines. Sub-thrust anticlines and truncations under sealing thrusts, as well as anticlines above buttress-related duplex anticlines and structures related to out-of-sequence thrusting, are suggested as smaller, challenging structural traps.

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