Pattern of structural geology underground in eastern of north DEZFOL embayment

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ABSTRACT

The study area is located in the eastern region of Dezful Embayment division structure is known. It's part one of richest belts Trust the world's. To study the structural regions of the field was studied by surface structures and for subsurface structures by seismic data of eastern North Dezful Embayment region will be. It was determined the geometry of the Zagros deformation front and front of the basin is controlled by minimum two different structural parameters (1) Mechanical nature of the separation rule shortening ZFTB and (2) Reactivation of basement faults effective in the tectonic model of crustal thickness. Structural style of the Dezful Embayment associated is with faulting and folding sliding surface. In the area of the sliding surface to evaporate a Gachsaran formation has created. It seems that the main reason for folding uncooperative is sliding between Gachsaran and Asmari by the difference in level viscosity.

Key word: structure, DEZFOL embayment, seismic data, surface study, Pattern

Introduction

The Zagros mountain belt of Iran, a part of the Alpine–Himalayan system, extends from the NW Iranian border through to SW Iran, up to the Strait of Hormuz. This orogeny belt is the result of the collision between the continental Arabian plate and the so-called Iranian block belonging to Eurasia [5,26]. These authors infer that the first compressive movements across the belt began during the Late Cretaceous due to the abduction of ophiolites on the northeastern margin of the Arabian continent. These movements accelerated and became more widespread following the continent–continent collision in Miocene time [8,25]. The convergence is still active at the present day, in a roughly N–S direction at a rate of approximately 25–30 mm yr\(^{-1}\) at the eastern edge of the Arabian plate [21]. This direction is oblique to the NW–SE trend of the orogeny belt. Earthquake focal mechanisms and the GPS velocity field [27] suggest partitioning of this oblique shortening along the faults in the Zagros [22].

The Zagros fold-and-thrust belt is the result of continental collision between the Arabian and Eurasian plates [26,5,13]. The onset of convergence started with ophiolite abduction in Late Cretaceous time [3] and continued with a main folding phase in Late Miocene time [10].

The foredeep depression started to develop in the inner Zagros after deposition of the widespread Upper Oligocene platform carbonate (Lower Asmari Formation) [23] and migrated southwestward down to its present position in the Persian Gulf [1].

Despite the interest in Zagros folds due to their major hydrocarbon reserves, and after extensive drilling by oil companies, geophysical and geological surveys, little has been published about the structural behavior of the sedimentary cover, the structural style and its relationship with sedimentary facies and evolution of the belt since the Late Cretaceous. O’Brien [19] was the first to divide the stratigraphic column into five structural divisions. (1) Basement group (Precambrian), (2) Lower mobile group (Hormuz salt, decollement level), (3) Competent group (Cambrian to Lower Miocene), (4) Upper mobile group (Miocene salt, decollement level), and (5) In competent group (Lower Miocene to Plio - Pleistocene, mostly clastic sediments) [22].

It has been suggested that a large proportion of Gachsaran salt was re-precipitated from Hormuz salt, extruded in diapirs east of the Kazerun Fault [19;17]. Diapirism in the Gachsaran was introduced by O’Brien [19] to explain decoupling between the preand post-Gachsaran level. Recently some authors used his model to illustrate disharmonic folding [7]. Sherkati et al. [24], based on new available seismic

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profiles, illustrated the kinematic evolution of Miocene salt layers. The principal aims of this paper are to (1) describe the mechanical and physical properties of the Gachsaran Formation, (2) describe its thickness variations, (3) discuss the kinematics of folding with regard to the plastic behavior of the Gachsaran Formation, and (4) examine the control of the Gachsaran Formation on sedimentation of the post-Gachsaran syn-tectonic deposits [1].

2. Regional setting:

Folding in the Zagros involves practically continuous series from Cambrian to Recent in age. The thickness and faces of the Paleozoic are not well controlled in the SW of the Izeh zone and Dezful Embayment due to the lack of outcrops and deep well data. In this study, Paleozoic thickness and faces are inferred from the minimum visible thickness on seismic lines and the extrapolation of few outcrops in Zagros fold belt. presents new structural subdivisions of the stratigraphic column, which consists of several competent structural units that are separated by incompetent levels resulting in a disharmonic fold style in the study area (Fig 1). This disharmony is the expression of the different mechanical behavior of the units, which seems to be more complex than what was described by O’Brien [19]. From the NE to the SW of study area, our classification is based on data such as the Dinar surface section (Lower Paleozoic to Upper Cretaceous), the Mokhtar well (Middle Cretaceous to Eocene), the Khami surface section (Jurassic to Oligo-Miocene) and the Nemours well data (Lower Cretaceous–Pleistocene) in addition to regional seismic interpretation and field mapping.

The main basal decollement horizon is located in Lower Paleozoic Hormuz salt or Cambrian Shale beds, over the entire study area. The Hormuz evaporite series is known from outcrops along the southern border of the High Zagros thrust [7], Fars region and also from seismic data in the Persian Gulf. Instead, there is no outcrop or seismic halokinesis evidence for Hormuz salt in Izeh zone and Dezful Embayment (Fig 1) [22].

In the Dezful Embayment, the Miocene Gachsaran Fm. is the main intermediate incompetent horizon. Its thickness changes very rapidly from several hundred to 2000 m. This thickness variation is related to faulting, folding and diapirism after deposition and also syntectonic sedimentation during the folding (Fig 1). It consists of salt at the base, which is overlaid by anhydrite, marls and thin-bedded carbonates. Our observations show differences in size, structural configuration and tectonic complexity of the structures across the study area which are interpreted as being related to sedimentary faces variations [22].

Fig. 1: Satellite Image of North Dezful Embayment area (Landsat 7)
3. Structure Study:

This Section is in 2 parts. First, we describe the Seismic data of the Dezful Embayment. Second, we describe the structure of the Embayment based on published accounts of the exposed and sub-surface geology, and our own field observations. Finally, we review the wider structure of the Zagros, with the particular aim of highlighting those features that vary along strike and may bear on the origin of the Embayment itself.

3.1. Geomorphology and surface Study:

Anticlines within the Dezful Embayment coincide with modest topographic highs, generally only a few tens of metres above the surrounding plains, which are themselves only a few metres above sea level. Upper Cenozoic clastic rocks assigned to the Agha Jari and Bakhtyari formations are exposed at the fold crests (Fig 2). The fossil-poor, terrestrial nature of these units means that assignments are done mainly on the basis of the lithologies, with little biostratigraphic control [12]. This practice means that some of the finer-grained strata assigned to the Agha Jari Formation are potentially time equivalent to coarser strata mapped as Bakhtyari Formation. The Ahwaz structure is an example of this: the uppermost exposed strata along the fold crest are mapped as Agha Jari Formation [18], which, if a strict layer cake stratigraphy applies, suggests that the fold has uplifted, exhumed and eroded the entire Bakhtyari Formation since some time in the Pliocene, or at least its non-deposition. This seems unlikely, given that the structure has only a few tens of meters of elevation above the surrounding alluvial plains (Fig 2). Modern drainage patterns and deposition make a similar point: drainage across the Dezful Embayment is centripetal, rising on all three mountainous margins and focusing on the Tigris in the southwest. Rivers at the margins of the Embayment are commonly braided and carry a cobble-grade bedload. Their downstream equivalents in the Embayment interior are typically meandering (such as the Dez and Karun,) and carry more fine-grained sediment (Fig 2). These two present settings probably typify much of the upper Cenozoic clastic sedimentation across the Zagros, with the fine-grained ‘Agha Jari’ type passing upwards into coarser ‘Bakhtyari’ sediments as deformation advanced towards a given area, thereby increasing relief and sediment grade (Fig 2). A further implication is that interpretations of pulses of deformation, based on unconformities beneath conglomeratic facies [8], need to be treated with caution. Such a sedimentary switch might represent...
the local progradation of higher energy transverse deposits over lower energy axial or centripetal systems, not a Zagros wide pulse of deformation. Individual folds interact with drainage systems, typified by the Sardar Abad anticline. This is a composite structure with four separate culminations along its length [15]. The topographic relief above surrounding plains is ~40 m. The Dez River is antecedent and cuts through the middle of the anticline. Notably this is not at one of the relay zones between the culminations, but in the middle of a culmination, at least at the present exposure level, which is mapped as the Agha Jari Formation (Fig 2). The river changes plan form from meandering to a relatively straight reach as it crosses the fold, reverting to a meandering plan form downstream, which is a typical response of low gradient rivers as they cross a zone of active surface uplift [9]. In contrast, the Karun River is diverted around the southeast tip of the fold, presumably tracking the lateral growth of the fold tip in the same direction. Lateral fold growth is preserved in higher relief anticlines at the margins of the Dezful Embayment, where wind gaps/dry valleys are preserved along fold crests, e.g. near the eastern tip of the Kuh-e Chenareh anticline. Such wind gaps are common in the Zagros [4,20], and are useful indicators of the previous patterns of drainage. The present drainage is diverted around the fold, lying some 3 km further east, but this channel also lies within the topographic expression of the fold and so may in turn become abandoned at some stage in the future. The rates of surface uplift and lateral fold propagation are unknown (Fig 5).

3.2. sub-surface Study:

Most events are located between the Dezful Embayment Fault and the Mountain Front Fault where topography is steepest (Fig 2). Higher regions (>1000 m elevation) to the northeast are less seismically active, although there are two oblique and strike-slip events recorded close to the Main Recent Fault and the Kazerun Line (Fig 3). One thrust earthquake took place close to the High Zagros Fault. Three events occurred close to the frontal anticlines of the Dezful Embayment, suggesting that these folds are underlain by thrusts similar to the structures further northeast. Combining the earthquake depths with depth-to-basement maps confirms that in places the Zagros basement is actively thrusting [11,16,28,29], but at the same time some seismic faulting occurs purely within the sedimentary cover(Fig 4) [14,2]. There is no difference in the orientation, magnitude or dip of events rupturing within the cover or basement, or both. There is some evidence for low angle (<20° dip) thrusting in the seismicity record, especially in the northeast of the Embayment, for example the 19 October 1980 event at 32°70′ N 48°58′ E at 17 km depth [16]. Other low-angle slip is likely to happen seismically, perhaps along weak detachment horizons (Fig 3) [6].

Fig. 3: Schematic picture seismic profile of the subsurface structure in 1-Naft sefid and 2- Lab sefid based on information provided by NIOC
4. Role of the Gachsaran evaporites in the dynamics of folding:

The stratigraphic column of the Zagros consists of several competent stiff layers that are separated by evaporite or shale layers, involved in deformation as intermediate decollements [19,23] (Fig 5). Plastic behavior of the incompetent units within the Gachsaran Formation favours development of disharmonic folding above it; such folding can be completely decoupled from that of underlying formations. Generally folds above the Gachsaran Formation are tight with short wavelengths in the Dezful Embayment. As explained before, the Gachsaran Formation is considered a main detachment level (upper detachment) in the Dezful Embayment (Fig 4). Therefore, the geometry of folds is expected to be different above and below this detachment level. A two-way time map of the top of the Gachsaran Formation (based on seismic data in the time domain with sea level as the datum plane) is presented in Figure 4 and 5 shows the location of the anticlines in both the top Asmari and Gachsaran levels. Therefore, the location of structures in the top Gachsaran level is clearly different from structures in the top Asmari.

5. Structures in the eastern 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 5). The Dezful Embayment contains many anticlines, 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 are shown in a migrated seismic profile. These anticlines are gentle, with rounded shape in cross-section (Fig 5). 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 growth of detachment or fault-propagation folds in the syntectonic deposits, where associated uplift and subsidence have created unconformities and on lap 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 and low-angle thrusts 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. The latter are hinterland dipping or ant formal 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 (Fig 5). The best example is represented by the Aghajari Anticline, 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.

![geology map of north Dezfol embayment](image)

**Fig. 5:** Schematic picture cross section of the subsurface structure in Izeh zone

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.
6. Discussion:

The greater part of the Zagros lies within the Simply Folded Belt, but this region is not homogeneous along strike, being an alternating sequence of low relief, low elevation ‘embayment’ and high relief, high elevation ‘salient’ or ‘arcs’. These quotation marks are advisable: the deformation front is distinctly linear along the Zagros west of the Kazerun Line, while the Fars region has an arcuate deformation front that does not step abruptly southwards of the eastern limit of the Dezful Embayment.

Variations along strike in the High Zagros occur at the same places as within the Simply Folded Belt, and the intense imbrication of the Bakhtyari Culmination is not matched by similar thrusting of the Arabian plate margin in regions to the northwest or southeast. This variation is consistent with an original promontory at this point on the Arabian plate margin, now smoothed out by the collision. We further suggest that this imbrication and thrust sheet loading resulted in greater subsidence of the Dezful Embayment than other areas of the Simply Folded Belt.

7. Conclusions:

(1) Thickness variations of the Gachsaran Formation, instead of sedimentary dynamism, are mostly related to flow and thrusting of its incompetent members (Fig 6).

(2) Usually conventional time-migrated seismic sections are distorted and obscured owing to the presence of Gachsaran ridges and related lateral velocity Neogene salt and Zagros folding variations. In such conditions, strong lateral velocity variations, related to lithology contrasts between steeply dipping layers, bend the seismic rays like an optical lens and distort the sub-surface image (Fig 6).

(3) Syn-tectonic Agha Jari and Bakhtyari deposits actively influenced the mechanical balance and the kinematic evolution of the folds developed in the Dezful Embayment.

(4) A possible mechanism for deformation of the Gachsaran Formation is flow of salt and of other incompetent rocks (members 2–5). Progressive deformation accelerated this mechanism and blocked incompetent sediments between pre-Gachsaran anticlines and post-Gachsaran synclines, squeezed up to the surface just after erosion of the superficial crest of Fars anticlines (Fig 6).

Fig. 6: Model for eastern region North Dezful Embayment

References


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