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Evolution and timing of salt diapirism in the Iranian sector of the Persian Gulf

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ABSTRACT

The Iranian sector of the Persian Gulf is affected by more than 30 large diapiric structures triggered by the mobilization of the Infracambrian Hormuz Complex, an evaporite-rich unit that overlies Precambrian basement at the base of the sedimentary succession. Nineteen non-piercing diapirs, without any appreciable salt intrusion into the upper succession, were studied in detail and retro-deformed by the decompaction and unfolding of 13 seismic horizons that were identified by the interpretation of a dense grid of 2D seismic lines and calibrated by well data.

Salt uplift had begun by the Early Palaeozoic and persists to the present day, with major pulses of intensity during the Middle Triassic, Cenomanian, Late Oligocene, and post-Middle Miocene. The structural reconstructions and the analysis of the progressive deformation of the study diapirs do not show any link between diapiric uplift and local tectonic structures, and no clear correlation with the regional geodynamic events acting at the boundary of the Arabian plate.

On the contrary, the salt uplift seems strongly influenced by the differential rate of sedimentation that affected the whole study basin (more than 40,000 km^2), with a coefficient of correlation between the salt uplift rate and the differential rate of sedimentation (expressed by the standard deviation of the sedimentation rate calculated over the entire basin) of 0.95. This downbuilding mechanism of diapiric growth is apparently induced by differential sedimentation over long distances (several tens of kilometers), showing that the flow of salt affected the whole basin and not just the areas around the single diapiric structures.

1. Introduction

The Persian Gulf is present along the NE collisional margin of the Arabian Plate, and it represents the foreland basin system of the Zagros fold-and-thrust belt (Fig. 1). This basin hosts a huge amount of sediment (more than 15 km deep near the Zagros foredeep) deposited since the Late Proterozoic. Almost the whole Persian Gulf is affected by large diapiric structures that are frequently associated with huge hydrocarbon traps like anticlines over the plug, fractured and faulted blocks of the overlying and surrounding beds, bending and sealing of the strata cut by the plug, and finally, the residual bulge left between two nearby plugs (turtle-back structures). The Infracambrian Hormuz Complex is the evaporite-rich unit that overlies Precambrian basement at the base of the succession in the Fars zone and triggers this significant salt activity. This unit, which is essentially composed of evaporites, local dolomites, and limestones and siliciclastic deposits, is regionally important because it acted as the principal detachment surface for compressional deformation (folding and thrusting) in the Zagros belt (Sharland et al., 2001; Carruba et al., 2006; Trocmé et al., 2011; Alsouki et al., 2011; Burberry et al., 2011). This is also confirmed by the fact that only few earthquakes with centroid depths greater than 15 km can be attributed to basement faulting with certainty, while the great part of large earthquakes in the Zagros are contained within carbonate rocks in the sedimentary cover and, consequently, the crystalline basement shortens mostly aseismically (Nissen et al., 2014 and references therein).

The aim of this paper is to describe the geological evolution of the diapirism in the Iranian Persian Gulf by the interpretation of a dense grid of 2D seismic lines, their depth conversion, and the generation of structural depth maps of some important horizons that have been calibrated with well data. As a result of a procedure that combines decompaction and unfolding that was applied to the structural depth maps, it was possible to evaluate the rates of sedimentation and salt activity from the Middle Permian to the Holocene. The 19 analyzed structures were diapiric anticlines that do not pierce the Mesozoic succession and on top of which the marker horizons were recognizable; the piercing diapirs, that in some cases warp the sea bed and form emerged islands (Motamedi et al., 2011), were only qualitatively examined. Salt activity in the region probably started during the Palaeozoic, immediately after the deposition of the Hormuz Formation (Motiei, 1995; Jahani et al., 2009; Chiariotti et al., 2011; Perotti et al., 2011; Motamedi et al., 2011), but no Lower Palaeozoic horizons calibrated by deep wells

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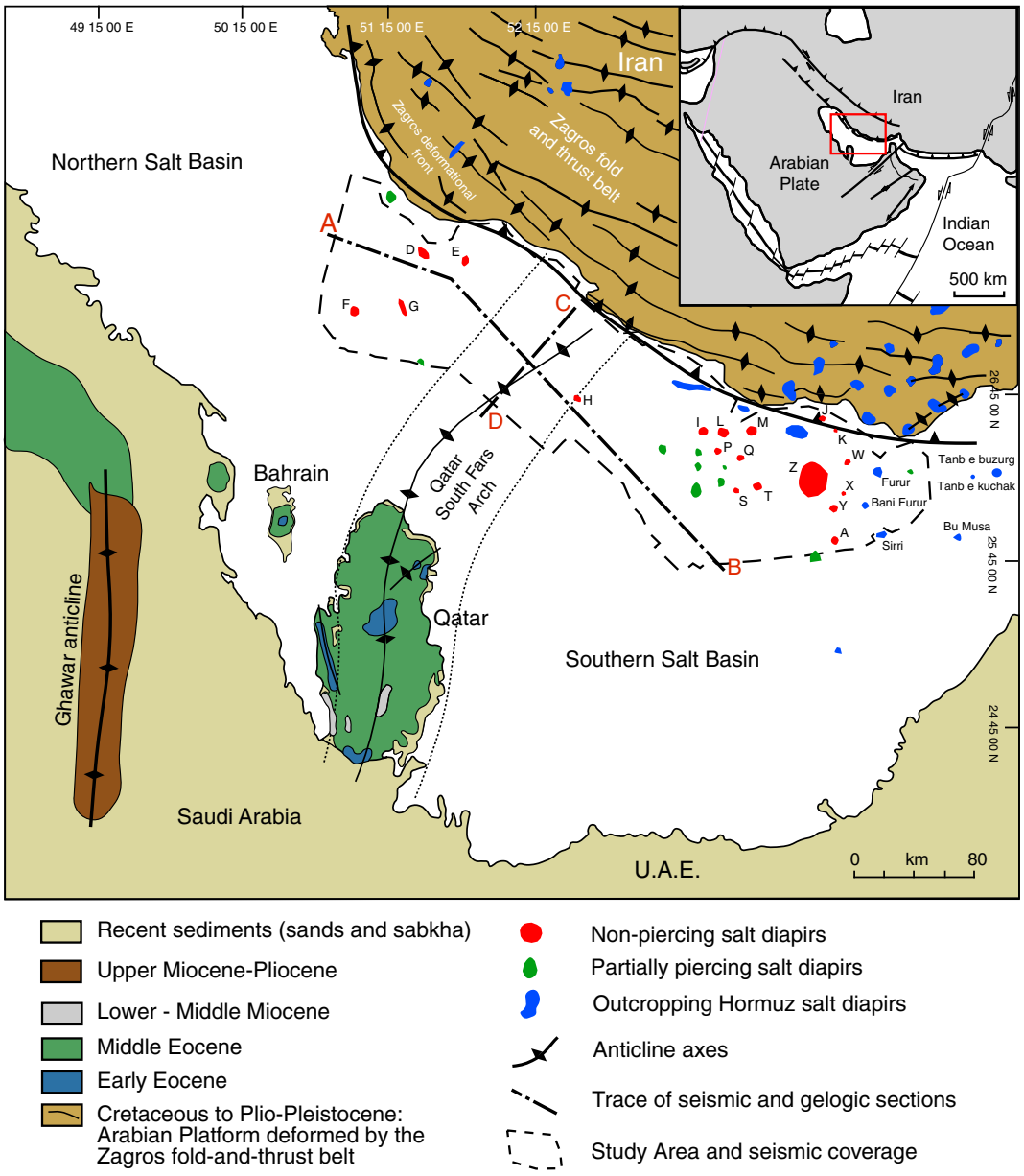

Fig. 1. Simplified geological map of the central Persian Gulf.

were identifiable, so the timing of the beginning of the salt activity still remains uncertain (Motamedi et al., 2011).

The evolution and timing of the different diapiric bodies have been reconstructed and compared in order to evaluate the possible triggers of the salt diapirism and the role assumed by the regional geodynamic regimes that affected the Central Persian Gulf Basin.

2. Geological setting

The study area has an extent of more than 40,000 km^2 and is located in the Iranian sector of the central Persian Gulf, from the Iranian coast to the northeast, to the boundary of the territorial waters to the southwest (Fig. 1). This foreland basin is characterized by a very thick sedimentary succession that accumulated from the Late Proterozoic to Holocene on the northeastern margin of the Arabian Plate (Ala, 1974; Beydoun, 1991; Edgell, 1996; Alsharhan and Nairn, 1997; Konert et al., 2001; Sharland et al., 2001; Ziegler, 2001; Burberry et al., 2011). The basin is wedge shaped with sediments gradually thickening from the southwestern Arabian Shield towards the Zagros Mountains to the NE, where they reach a maximum thickness of more than 15 km (Edgell, 1996).

Immediately south of the present-day Zagros deformational front, which runs approximately along the shore of Iran, the sedimentary succession is slightly deformed by several Infracambrian Hormuz salt-cored diapirs that form broad, kilometric, low-relief anticlines (Edgell, 1996). In addition, some elongated anticlines in the Arabian Platform and Persian Gulf have cores of deep-seated salt (Edgell, 1992). The Infracambrian Hormuz evaporites were deposited at the end of the Proterozoic in several evaporitic basins located in the Persian Gulf region, and registered a steady diapiric rise during the Early Palaeozoic (Carruba et al., 2007), as well as several main phases of salt movement in the Permo-Triassic, middle Cretaceous, Eocene–Oligocene, and Neogene (see also Sugden, 1962; Edgell, 1996; Al Husseini, 2008).

The diapirs are subdivided into two salt sub-basins by a main regional N–S trending basement structural high (the Qatar–South Fars Arch) (Fig. 1). It is a very large (over 100 km wide and 300 km long) and long-lasting (several hundreds of Ma) warping of the Phanerozoic sedimentary succession of the Arabian Platform, belonging to the