Abstract

Hundreds of opening-mode clastic dikes crosscut the Lisan Formation. They are exposed in Ami'az Plain, Massada Plain, and near Nahal Amayyahu. The main possible mechanisms of the clastic-dike formation are response of the Lisan host rock to a regional (tectonic) stress field or local stress field (e.g., around an emerging salt diapir), effect of pore pressure and hydro-fracturing, dynamic (e.g., earthquake-related) fracturing, jointing due to material shrinking (i.e., mud cracks in claysey sediments) and combination of the above mechanisms. In order to differentiate between the different mechanisms and better understand the spatial distribution of the clastic dikes in the Dead Sea basin, we studied the orientation and geometry of these dikes and characterized their infills.

In Ami'az Plain the dikes form a radial and tangential pattern over a range of ~120°. Many of them cut the whole Lisan section and are mainly composed of green clay that derived from the lower Lisan section. In Massada Plain the dikes show a wide range of orientations between 270° and 00° with only a slight clustering around a NNW-SSE direction. They cut the whole Lisan section and compose of clastics from the lower Lisan Formation, including some pebbles derived from detritus Lisan layers. Next to Nahal Amayyahu the clastic dikes form a polygonal pattern with abundance of “T-junctions”. They cut only the few upper meters of the Lisan Formation. A preliminary study of their brown silty infills suggests that it is not derived from the Lisan Formation. The dikes in Ami'az Plain were injected during earthquake events and their pattern were dictated most probably by superimposed static (slope-creep) and dynamic (earthquake-creep) stresses. The pattern of the clastic dikes in Massada Plain (with supportive indication of their infills) resembles that of dynamic fracturing and could be associated with earthquakes along the nearby strands of the Dead Sea fault. The dikes next to Nahal Amayyahu form as mud cracks due to desiccation of the Lisan Formation during a low stand lake level. While the clastic dikes in the three studied areas are distributed in a similar area size within the same lithology, our study shows that their origins are more complex and might be related to different mechanisms.

Possible mechanisms of the clastic-dike formation:

1. Dynamic fracturing

Livi et al. (2005) suggested that the high pressure values represent the static stress drop during earthquake events or represent dynamic stresses resulting from the seismic waves which passed through the salt diapiric rocks. Livi et al. (2005a) demonstrated clastic dikes which formed by injection of material from that layer into the Lisan Formation. The particle-water mixture, which is injected under differential pressures, is being bounded by host rock, requires a sustained pressure difference between the mixture in the source layer and the mixture in the propagating fracture.

2. Regional (tectonic) stress field or local stress field

Joints and dikes are opening-mode fractures that propagate in the plane of α1 and α2 and normal to α3, and thus are sensitive indications of the local stress field orientation (Dyer, 1989; Pollard and Aydin, 1988). Because vertical joints, dike patterns (Muller and Pollard, 1979) and systematic joints (Endinger and Gaiser, 1980) align parallel to the trend of the maximum horizontal stress (σHmax), they are used to construct regional paleostress trajectories.

3. Desiccation cracks

Desiccation cracks form networks of interconnected tension fractures arranged in polygonal patterns, which have been described widely in the geological literature (e.g., Allen, 1985; Weinberger, 1989; Weinberger, 2001; Massaro et al., 2005). Cracking of mud, which involves a substantial volume loss, is evidently very different from cracking of ordinary rock masses. Mud cracks typically intersect at right angles. This is because the first opening-mode crack produces two traction-free surfaces; a second crack tends to approach the first crack orthogonally to these surfaces in order to satisfy these boundary conditions (Lachenbruch, 1982).

Clastic dikes

Clastic dikes are discordant, tabular bodies composed of weakly to strongly lithified clastic debris. The mechanism of clastic dike formation is not fully understood, and interpretation of field observations is commonly ambiguous (e.g., Aspen and Desloge, 1985). Two main mechanisms have been proposed: (i) depositional clastic dikes formed by passive deposition of clastic material into preexisting fissures that are open to the Earth's surface (e.g., Eyal, 1988); and (ii) injection clastic dikes formed dynamically by host-rock fracturing and injection of un lithified clastic sediment slumps from below.

Clastic dikes of about 130 cm in length cut the Lisan Formation between 270° and 00°, with only a slight clustering around a NNW-SSE direction (Fig. 11). Their geometry hints at the role played by internal pressure during clastic emplacement and horizontal transport of clastic material into the evolving dikes. The dikes show a wide range of orientations between 270° and 00° with only a slight clustering around a NNW-SSE direction (Fig. 11). Noteworthy, morphological features such as sinkholes, gullies, and 1st order channels are dictated by similar orientations.

Summary

The three studied areas in the Dead Sea basin are similar in size, lithology and number of exposed dikes. Nevertheless, the formation of the clastic dikes varied. In both Ami'az Plain and Massada Plain the dikes formed due to dynamic fracturing but the orientations of the dikes in Ami’az Plain were apparently controlled by static stresses of exsated by salt tectonics. The dikes in Nahal Yechealya formed due to desiccation of the Lisan Formation during a low stand of the lake level.

Distribution and possible origins of clastic dikes in the Lisan Formation, Dead Sea basin

Jacob Y., Weinberger, R., Levi, T., and Marco, S.

1. Department of Geophysics and Planetary Sciences, Tel-Aviv University, Tel-Aviv, 69978
2. Geological Survey of Israel, 30 Maltke Israel, Jerusalem, 95501