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Origin of an extensive network of non-tectonic synclines in Eocene limestone of the Western Desert, Egypt

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Over the past six years, we have used remote sensing, field work, and geophysical surveys to study an unusual and extensively developed network of thousands of synclines in early Eocene limestones in Egypt. These synclines are not typical tectonic fold structures in either scale or geometry. Individual synclines are narrow (100-400 m wide), and syncline scale is strikingly similar everywhere, with no parasitic folds and no larger structures. In many parts of the network, narrow synclines occur with no companion anticlines, and synclines occur as isolated structures 1-3 km apart in otherwise flat-lying limestone. Broad structures that one might describe as anticlines do occur, but these are "accidental" and formed by proximity of two adjacent synclines. Limb dips are shallow, and fold hinges plunge shallowly. Many synclines are several kilometers long with multiple basin closures along their length. Some occur as isolated basins. Two dominant orientations are common (NNW-SSE and WNW-ESE) and are parallel to two prominent joint sets, but synclines from the two trends branch, merge, and curve into one another, forming a network. A quasi-polygonal network of ridges characterized by calcite vein networks coincides with syncline keels in portions of the network. The syncline network is cut by faults associated with opening of the Red Sea, and the network was eroded prior to deposition of fluvial gravels of the Katkut Formation, which pre-dates incision of a through-going Nile in the late Miocene. Both support an Oligocene/early Miocene age for the synclines. Although the synclines are not equally well developed everywhere, we have found them in Early Eocene limestone over an area of nearly 100,000 km^2 across the Western Desert Limestone Plateau and in smaller areas of the Eastern Desert.

The syncline network is best explained by non-tectonic sag of limestone layers accompanying volume reduction at depth, producing sag features similar to those caused by deep mine collapse. The mechanism for volume reduction, however, remains unclear. Dissolution of evaporites at depth is precluded by lack of evaporites in the underlying stratigraphy. Collapse of paleokarst is also unlikely, given the lack of evidence for long-term subaerial exposure in older limestone-bearing sequences. Consistency of orientation of synclines over huge areas suggests that subsurface mobilization of shale is unlikely. Hydrothermal dolomitization at depth is a possibility. Although we see no evidence for dolomitization in any of our samples, it could conceivably be confined to deeper areas in the limestones. Localized volume reduction accompanying conversion of biogenic opal A to opal CT, as proposed by others for sag synclines above North Sea polygonal faults, is a possibility, although previous workers studying chert in these limestones have failed to find siliceous microfossils. Our current preferred model is hypogene speleogenesis, with aggressive fluids moving upward along joints and faults in the Esna Shale and into overlying Thebes limestones, causing dissolution at deep levels and sag at shallower levels. We speculate that mafic igneous activity, which was widespread in Egypt after the early Eocene, could have played a critical role in creating aggressive fluids.