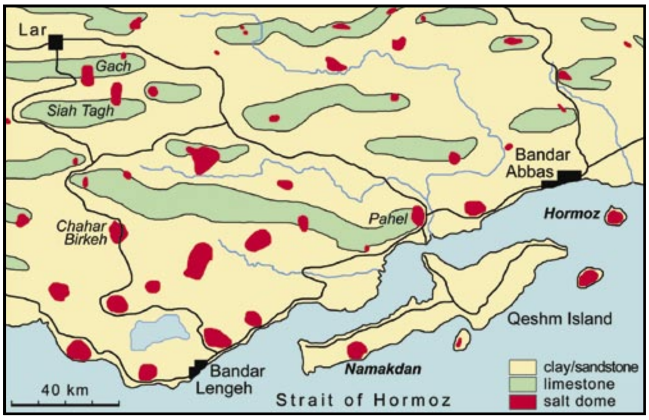
LECTURE

Salt terrains of Iran

A lecture given to the Society on Saturday 13th December 2009 by Dr Tony Waltham, Editor of the Society's Mercian Geologist.

The 130 salt domes in the southern Zagros are eroded into some of the world's finest landscapes of salt karst, and they also contain the world's longest and largest caves in salt. Beneath most of the Persian Gulf region, the kilometre-thick bed of Hormoz Salt lies at depths of 4-10 km, but it has also been mobilised into diapirs that intrude its cover rocks and reach the surface in more that 200 salt domes. In the desert climates of the region, with about 170 mm of annual rainfall in the coastal regions, the salt survives at outcrop.

Compared to nearly all other rocks, salt is extremely soft and mobile, so it flows as diapirs that intrude through other rocks on a scale only matched by molten magma in igneous intrusions. The driving force behind diapirs is the positive buoyancy of salt because its density is so much lower than that of other lithified rocks. At depths of 5 km or more, the huge overburden pressure is enough to squeeze the salt into any weakness in the same overburden rocks. The movement commonly starts with some fault displacements, but once established a diapir can push its way up through any cover of much stronger sedimentary rocks. Many of the Zagros salt diapirs rise through the anticlines of cover rocks, for which the Zagros are justly famous, but the anticlines probably grew by lateral compression of an initial fold created by the salt diapir.

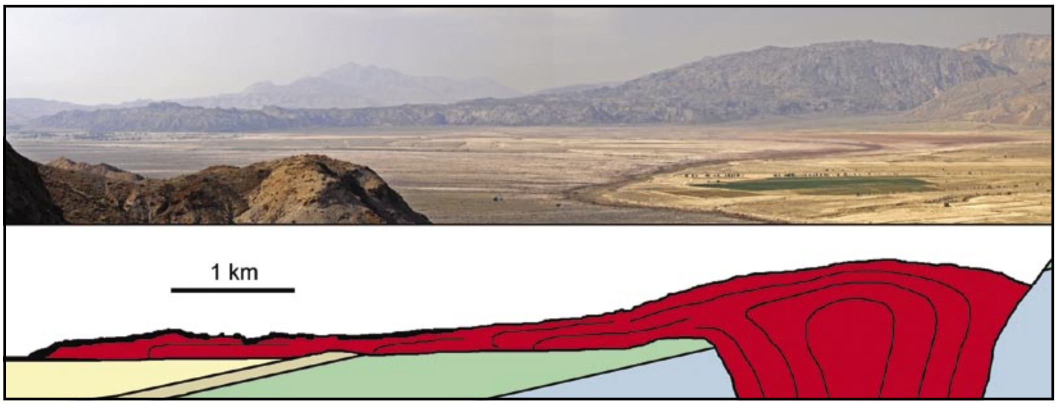


Geology of the coastal Zagros Mountains around Bandar Abbas.

Almost vertical banding within the salt, with some flow folding on the right, exposed in the roof of Fatima Cave, within the salt dome of Hormoz Island.

Domes and glaciers of salt

When the rate of diapiric uplift exceeds the mean rate of dissolutional loss beneath soil cover in the desert regimes, the salt rises to form domes that stand hundreds of metres above the surrounding countryside. Most of the domes are 1-10 km across, and their great domed mountains have bare outcrops of white salt that gleam in the sunlight, though much of their surfaces are masked by red soils. The main caprock soil, generally some metres thick, is a residuum of the insoluble components from within the original salt beds. This is dominated by clays and silts, but commonly contains up to 50% gypsum. The red colour is derived from up to 15% iron oxides, mainly in the form of earthy hematite, but there is abundant black specularite on some domes. The cover rocks are commonly upturned around the edges of the domes, with some remnants extending up onto the salt outcrops. The existence of these mountains of salt requires that their underlying diapirs are still rising. Typical uplift rates for those in the Zagros are 2-6 mm/year, though some appear to be growing at up to 15 mm/year.



The Gach salt glacier; seen from the west in a photograph taken from on the Siah Tagh glacier, and drawn in a sketch section.

Rugged terrain near the northern margin of the Hormoz salt dome, with doline karst well deveoped in the soil cover over the cavernous salt.

Where diapiric uplift far exceeds surface erosion, the excess of salt becomes unstable as a high dome, and flows away as a salt glacier. With morphologies somewhere between ice glaciers and lava flows, salt glaciers are extruded from rising salt domes, to simply flow at mean rates of a few metres per year down into an adjacent synclinal valley. They can reach lengths of 5 km or more, with widths typically of a few kilometres between steep margins that stand 100 m high. Each glacier advances in a tank-track motion, rolling over itself as the salt is deformed into recumbent folds; analogies are drawn with alpine nappe systems. Unlike in an ice glacier, there is no basal shear, and a better comparison is drawn with an aa lava flow with its hot core advancing over cooled rubble. The salt glaciers of Gach and Siah Tagh, near Lar, are fine examples. Their surfaces are mantled by thick residual soil that is carved into badland topography of steep gullies and sharp ridges with little exposed salt. Dolines are recognisable on some glaciers, and small streams emerge from the toes of some, but karst landforms are subordinate to those produced by the glacier movement.

Flow rates have been estimated and measured on salt glaciers around Bushehr (far to the west of Bandar Abbas) by Chris Talbot and colleagues from Uppsala and Shiraz universities. Mean flow rate appears to be around 2 m/year, though old maps indicate that the front of the Kuh-e-Jahani salt glacier has advanced about 200 m within 25 years.

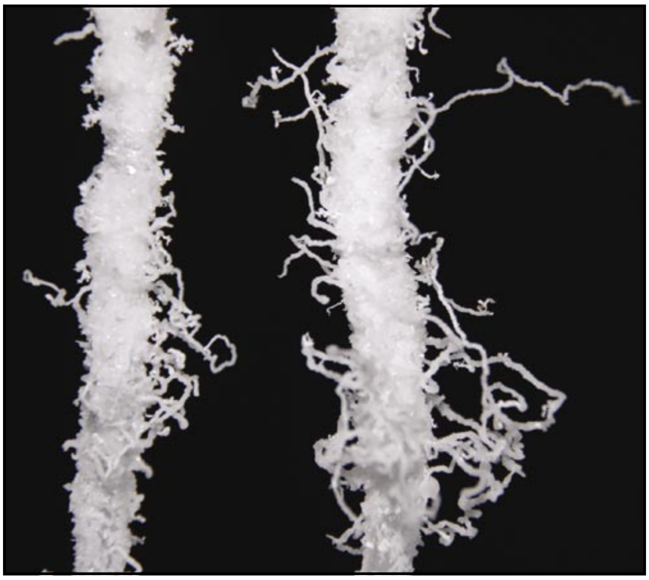
Karst and caves in the salt

Even in the deserts of Iran there is enough rainfall to create spectacular karst topography on the highly soluble salt. Karst landforms are best developed on the stable salt domes, and are especially splendid on the coastal salt domes of Namakdan and Hormoz, where they have been well documented by Czech geologists led by Pavel Bosak. The net effect of dome denudation is to create spectacular doline karst. At the kilometre scale this is polygonal, with networks of interfluves around closed depressions that each drain into a central sinkhole or cave. Etched into the polygonal relief are thousands of closely packed dolines, each 5-30 m across. Most of these are partly or largely formed within the red caprock soils, but they reach downwards into open shafts or choked sinks within bedrock salt. Rapid dissolution of the underlying salt creates areas of spectacular instability where the soils are actively collapsing into open voids on a scale that makes just walking across the land distinctly exciting. All stream courses that emerge from caves appear as streaks of white across the landscape, where the brine has deposited thick crusts of sparkling white salt crystals.

Beneath the red soils and the doline karst, cave passages carry the ephemeral drainage through the solid salt. To date, just a few have been explored and mapped by the Czech geologists. Their finest discovery has been the Tri Nahacu Cave has more than 6 km of passages, many of them more than 5 m high and wide, reaching

Bedrock salt with a thick soil cover, exposed beside a stream channel that is floored with crystalline salt on the Hormoz Island salt dome.

between a sink and a resurgence that lie 2 km apart in the Namakdan salt dome. Though the cave is almost entirely of Holocene origin, the rapid salt dissolution has already allowed it to evolve to an almost perfectly graded profile; it descends steeply from the sink, but then has only a very gentle gradient right through to its resurgence. Between large chambers and spacious galleries, there are low sections of passage where silt and clay sediments have accumulated to levels less than a metre below the roof. With salt dissolution concentrated at the water table (above the denser brine), many of these passages are now up to 50 m wide. Some chambers have broken roof profiles left by block collapse, but others have smooth arched profiles created by granular disintegration of the coarsely crystalline salt. These salt caves are still very active, and large blocks of bedrock salt fall from their ceilings at a frequency far greater than the very rare cave roof failures in limestone.



Helictites on salt straws in one of the smaller caves in the Namakdan dome; the two vertical straw are each about 4 mm in diameter, and the helictites growing from them are very thin and very fragile.

The caves are also remarkable for their abundance of beautiful, pure white, salt decorations. Dominant are thick stalactites up to 4 m long. Most of these are curved, because they formed as lattices of salt crystals that could grow away from the vertical, before gathering overgrowths that gave them their smoother final profiles. There are also clusters of long thin straw stalactites, again made of salt, each with a diameter little more than that of a drinking straw. These are remarkable for their overgrowths of tiny helictites that twist away in all directions, again the product of randomly orientated crystal growth.

All these snow-white deposits of crystalline salt are exceptionally beautiful, and these splendid decorated caves beneath the ground complement the spectacular surface landforms to place the salt domes of Iran among the more remarkable and unusual geological terrains known anywhere in the world.

Literature

Bosak, P., Bruthans, J., Filippi, M., Svoboda, T. & Smid, J., 1999. Karst and caves in salt diapirs, S E Zagros Mountains, Iran. *Acta Carsologica*, **28**(2), 41-75.

Kent, P.E., 1970. The salt plugs of the Persian Gulf region. *Transactions of the Leicester Literary and Philosophical Society*, **64**, 56-88.

Talbot, C.J., 1998. Extrusions of Hormuz salt in Iran. *Geological Society of London Special Publication*, **143**, 315-334.

Waltham, T., 2008. Salt terrains of Iran. *Geology Today*, **24**, 188-194.

A small chamber along an old cave passage within the Namakdan dome, with a profusion of salt crystals and stalactites growing down from its ceiling.