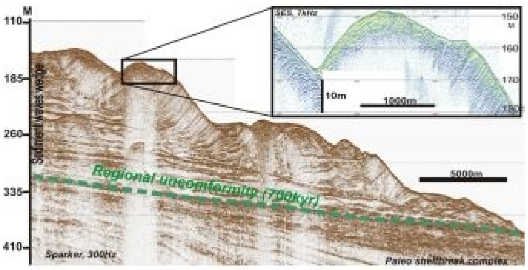
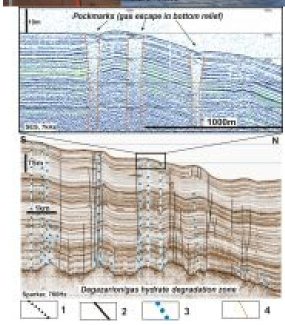
GEOHAZARD OR GEOFEATURE?

Sediment Waves





The term ‘sediment waves’ was fully established in a special issue of *Marine Geology* and refers to large-scale depositional bedforms in various parts of the world’s oceans. These undulating objects usually have tens of metres to a few kilometres in wavelength and a height of several metres. The genesis is believed to be a near-bottom current, a turbidite current or both. The main issue about the sedimentary wavy features was, and is, to distinguish them from soft sediment deformations (creep). The methods used for such determinations are accurate processing of seismic sections to reveal whether the faults are real, measuring granulometric distribution on the top of the structures, analysis of regular morphology compared to obvious distribution laws, and form analysis of crests in plan view. However, the ’current vs creep’ argument is still common, even for some well-known ’wave fields’.

Worldwide investigations during the last decade revealed these controversial geomorphologic features in different geological and paleogeological environments, including ones connected to oil, gas, and gas hydrates fields. The fact that sediment waves cannot only be confused with but can be complicated by creep processes , is evidence for present or past active sedimentary environments, e.g. turbid flows, gas eruptions and the fact that they can be small-scale reservoirs for free gas and fluids, lead to the assumption that the presence of these geo-features may be a direct indicator of ‘a geological state that represents or has the potential to develop into a situation leading to damage or uncontrolled risk’ e.g. geohazard. However, the same facts also reveal sediment waves as treacherous features.

Due to recent increased awareness of ecological consequences of offshore exploration, geohazard estimation has become the first thing to do, especially in the marine environments. Since any sea is very sensitive to all external impact, information on risk criteria is vital. Processing of seismo-acoustic data and analysis of acoustic field anomalies are primary methods of geophysical surveys. Re-interpretation and comparative analysis could be of much help in estimating potential hazards and especially in distinguishing perilous settings and safe geo-features. The paper represents such analyses made by P.P.Shirshov Institute of Oceanology RAS on examples from the Caspian Sea.

Geological Setting

The Caspian Sea is a huge (1,200km x 300km) in-land depression, isolated from world oceans. Morphologically, the Caspian Sea can be divided into three regions: Northern (vast shelf plains), Central (depression, average depth 300m, maximum depth – 700m) and South (depression, average depth 500m, maximum > 1,000m). Natural borders of these regions are the Mangyshlak Threshold (sediment bow-shaped body) between the North and the Central parts and the Apsheron Threshold (linear tectonic elevation) between the Central and South parts (Figure 1). Significant regional processes are neotectonic movements and a great number of deep-focus earthquakes (up to a hundred per year). These tectonic movements initiate mud volcano activity and mass movements on slopes of both deep basins. On the other hand, sedimentation processes in the Caspian Sea are mainly controlled by bottom topography and sources of sedimentary material (first of all river runoff). The most famous Caspian peculiarity is its ever-lasting unpredictable level-change which does not correlate with the world oceans or with glaciation history.

Major hydrocarbon fields are situated on the Northern shelf and in the deep Southern basin and several prospective structures occur in the Central basin. There is a general distribution rule: main oil fields are situated northward from the Apsheron threshold and main gas fields southward. Such situations have occurred due to the sedimentation history and heat flow, which is especially large near the Apsheron threshold. Nevertheless, gas-saturated sediments in different forms occur nearly everywhere in the Caspian Sea. The most common acoustic anomaly for such sediments is ‘bright spot’, but spectacular gas pipes exist as well.

In addition to oil and gas fields, the Caspian Sea seems to have several fields of gas hydrates with different gas types. During intensive exploration in the South Caspian gas hydrates were discovered offshore Azerbaijan both on the top of mud volcanoes and in fairly undisturbed sedimentary sections by clear seismic BSR.

Study Methods

During recent investigations by the P.P. Shirshov Institute of Oceanology, seismo-acoustic data was acquired by several hardware sets (Table 1, Figure 2). A global positioning system (DGPS) provided vessel position with an accuracy 0.5-5.0m. Polygons consist of orthogonally or obliquely crossing survey lines. The deposits have been sampled with gravity cores 15cm in diameter and up to 4m deep. Grain size analyses were made in MSU laboratories with standard methods. Volume density of unstrained and wet sediment was calculated by a cutting ring method. The seismo-acoustic data was processed in RadExPro, a seismic processing program, with standard algorithms (muting, filtration, sometimes deconvolution). Plastic models, based on density and geometry, were calculated in FLAC^{3D}.

Results

High-resolution seismo-acoustic data show distinct zones of geomorphology and acoustic anomalies: bright spots and numerous filled paleovalleys in the Northern Caspian; fans and paleodeltas on Mangyshlak threshold with creep zones and channel systems down to the Central basin; gas chimneys and unexpected mud volcano in the basin itself; series of modern faults on the Apsheron threshold; several fans and gas escaping zones in the Southern Caspian.

The most significant event of recent years was the discovery of several types of sediment waves on slopes of the Central basin. The largest (~150km x 50km) field is situated on the western slope of the Central Basin (Figure 3). Previously, these forms were interpreted as creep, but reinterpretation of old and the collection of new data showed all distinctions of mixed sediment waves (see the beginning of this article). There are several generations of waves, interbedded with parallel deposits. Geological samples show numerous sand/clay thin layers. The whole sequence age is 700kyr and it has the form of a wedge between the shelf break and the steep step down to the abyssal.

The second area of sediment waves is on levees of channels/canyons on the Mangyshlak Thresold. A fan of paleo Volga, paleo Terek and paleo Ural represents a highly complicated system with inflows and meanders, both recent and old (up to 600 kyr). Sediment waves on levees show differences in morphology, probably because of not precisely normal transections. Samples show thin material (clay). Recent studies (2012) reveal a third sediment waves field on the northern slope of the Apsheron threshold, but this will be a topic for future research.

In the close vicinity of the levee there is a creep area. Folds have 'classical' creep shape: flat tops, narrow valleys, irregular morphology and geometry. As on other 'wavy' fields, there are several 'generations' of creep folds, each slightly different from the others. Geological cores show water-saturated plastic clay.

Due to tectonic activity in the region, there are many faults on different scales. These features are inevitably connected to vertical zones without correlation (pipes and chimneys). Most of these zones end with pockmarks in bottom relief (Figure 4). The other ends connect with vast zones of chaotic reflections, both in the Central and the South Caspian. Northward from the Asheron Threshold there are three such zones on different levels, one of which occasionally occurs just below Holocene sediments.

Discussion

Due to recent increased interest in gas hydrates and the awareness of the ecological consequences of hydrocarbon exploration, the author paid special attention to the correlation between sediment waves, gas escape structures and gas hydrates with their visual evidence in bottom-simulating reflectors (BSR). All these features seem to show up together with hydrocarbon fields. The most obvious explanation for this correlation could be an unstable environment which works two ways: endogenous processes form rough relief causing trigging, sedimentation results in wavy forms, which could a) be unstable or b) accumulate escaping gas due to the presence of well sorted sediments. Most noticeable is the escaping of free gas below BSR or from dissociated gas hydrates layers. This correlation is not absolute and requires further investigation. However, it is possible to classify two types of 'gas to sediment waves' relation: a) direct escape of gas through wavy features; b) geological association 'sediment waves – BSR' on seismo-acoustic transects.

Modelling of plastic deformation shows that the wedge of sediment waves on the Derbent slope is stable, while creep on the northern slope is continuously flowing. In between the sediment waves and the creep is a channel system, which points to active hydrodynamics in the recent past or present. Several levels of this system have 'bright spot' anomalies and a series of possible gas-escape unconformities. Most of them are connected to channel levee sediment waves, both modern and paleo. Thus it is possible to declare that in the Central Caspian, sediment waves are proof of geohazards [Putans et al., 2010].

Close to the Mangyshlak threshold an acoustic anomaly of great disturbance starts. This anomaly is connected to gas pipes and is believed to be a weak layer of dissociated gas hydrates (Figure 4). Presence of free gas could be dangerous for drilling in nearby structures and further southward. Data from the Apsheron Threshold and the Southern Caspian provides evidence of shallow BSRs. At the same time, Caspian data shows an interesting acoustic pattern as a mirrored reflection. This acoustically sharp layer 'mirrors' the bottom relief in such a way that at a first glance it could be confused with BSRs. An interesting fact is that such effects occur near gas escaping areas.

Conclusion

Are sediment waves geohazards or just geo-features? After 'wavy' morphology was classified as creep, we are talking of geohazards even though many of these structures are undisturbed accumulative objects. Every sediment wave field has been formed in an active environment such as water flow or turbidities. These are treacherous processes, especially for pipelines: erosion could cause stretching while intensive sediment input could bury a pipe. Other exploitation and exploration risks are solifluction under pressure below a platform basement and gas explosion. The only thing that can be said with certainty is that flow and fluxes are not the only geohazard sediment waves can be connected with. Therefore, geo-features such as sediment waves should serve as a warning sign to start thinking in advance of the anthropogenic impacts and to take care of the sea.

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Type	Function	Frequency range (kHz)	Penetration (depend on sediments)	Vertical resolution
Sparker	Seismo-acoustic	0.2-0.7	50m - 300m	2-3m
SES – 2000 standart	Echo-sounder + seismo-acoustic profiler (tone signal)	100kHz 4-12kHz	10m - 50m	0.05-0.15m
CHIRP-II	Seismo-acoustic profiler with swip signal	2-7 kHz	2m - 50m	0.2-0.5m

Table 1: Hardware parameters.

More Information

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