SILVERPIT: THE MORPHOLOGY OF A TERRESTRIAL MULTI-RINGED IMPACT STRUCTURE.

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Introduction: The Silverpit impact structure was discovered during 2001 on three-dimensional (3D) seismic data obtained during routine hydrocarbon exploration in the southern North Sea [1]. It is now known that five commercially-acquired 3D seismic datasets partially cover the structure and approximately 80% of Silverpit is imaged by high-resolution 3D data (Figure 1).

Two boreholes had been drilled through the structure during the 1990's. The results of detailed analysis of cutting samples are not yet available to confirm the impact origin of Silverpit. However, the morphology of the central crater-form strongly suggests a complex impact crater [2].

Unusually for terrestrial craters, Silverpit is surrounded by up to ten concentric deformation rings, extending to 10 Km from the crater centre. These rings are closely spaced in relation to the total diameter of the structure, resembling Valhalla-type craters seen on icy satellites such as Callisto and Europa [3].

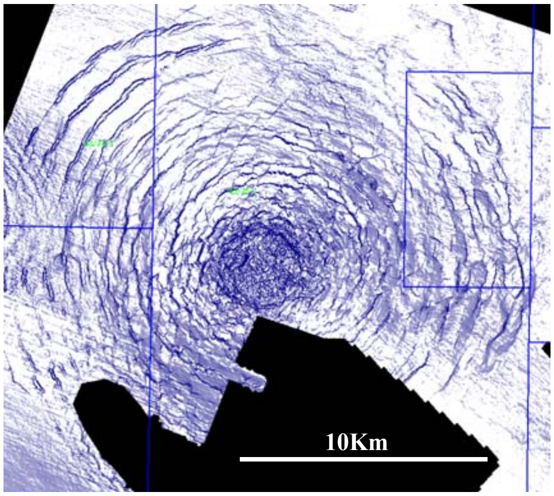

Figure 1: Top Chalk edge enhancement map. Dark colours represent steeper dips. Blue lines are hydrocarbon production licence blocks.

A further complication is that the geometry of the ring structures on the eastern side of the structure differ markedly from those in the west. The western deformation is clearly extensional, whilst several of those on the eastern side are compressional.

Following impact, there has been little or no erosion over most of the structure. There has been some gentle folding and Silverpit is now preserved under 500 to 1000 metres of sediment.

The Central Crater-Form: The impact has obviously affected Cretaceous rocks and possibly sediments of early Tertiary age. During most of the period between 60 and 65 million years before present, the region was a shallow sea. We assume the impact to be marine with water depths probably no greater than 100 metres. The sea bed of the time consisted of a relatively poorly consolidated layer of chalk approximately 500 metres thick.

The crater morphology can be mapped in detail (c.10 m 3D grid) on two key stratigraphic horizons: the Top Chalk and the Base Chalk. Additionally, structures such as faults can be mapped at the same high resolution.

The Top Chalk horizon shows a 3 Km diameter circular depression and a central uplift 250 m high (Figure 2). The blocky nature of this horizon may be attributed to resurge [4]. The seismic amplitude of the Top Chalk reflection within the crater is much reduced, partly as a result of this "blockyness" and partly because of a reduction in the velocity-density contrast due to increase in porosity [5].

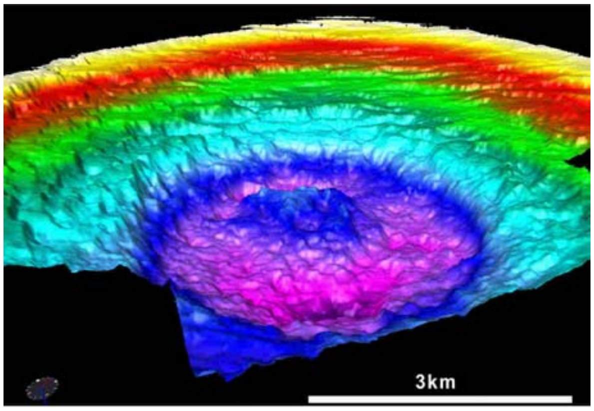

Figure 2: Perspective view of the Top Chalk interpretation. (Colour-coded depth.)

The Base Chalk reflection shows a well-defined central peak modified by a series of radial faults. Beneath this central uplift, the Top Triassic reflection shows a slight depression that we believe to be an imaging velocity effect caused by fracture porosity within the central peak.

Anomalous, high-amplitude reflections within the overlying Tertiary stratigraphy are spatially related to the impact structure and are evidence of localized post-impact subsidence. This is probably caused by differential compaction of impact-related porosity.

The Ringed Deformation Structures: In the western and north-western parts of Silverpit, the ring structures are characterised by normal, extensional faults, which are clearly delineated at the Top Chalk. Towards the centre of the structure, these faults define a series of inwards-facing terraces. In the outer regions, up to five extensional concentric graben are bounded by normal faults. These graben are typically about 100 metres across and 50 metres deep. All these faults die out within the lower layers of the Chalk formation and do not affect the Base Chalk (Figure 3).

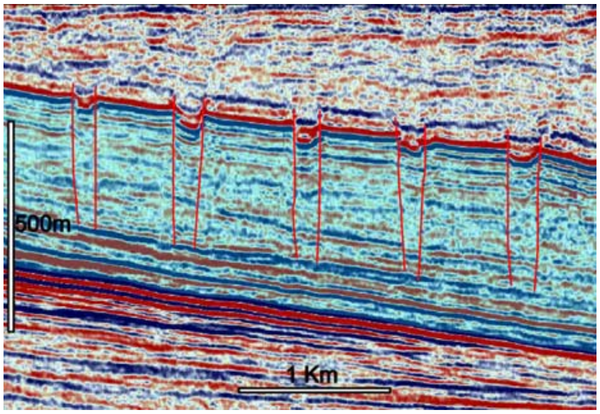

Figure 3: Seismic section showing the western ring graben. (The Chalk formation highlighted in blue; fault interpretation indicated by red lines).

To the east, the ring structures have a different morphology. Instead of being negative features, they are positive ridges, as observed at Top Chalk (Figure 4). In places these ridges are bounded by steep, possibly reverse, faults. In other areas, they are unbroken folds, again elevated above the regional surface. These features suggest compressive forces rather than extension.

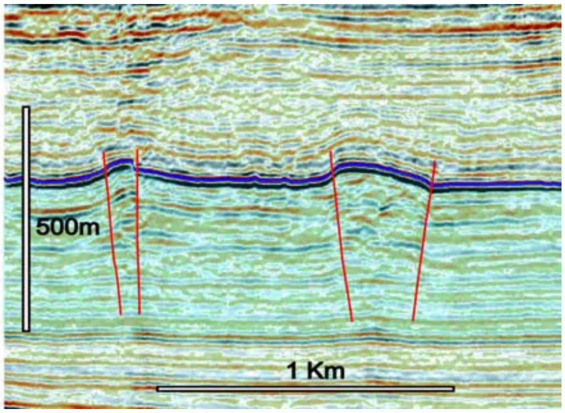

Figure 4: Seismic section showing the eastern rings.

In the northern sector of the structure, the ring development is more subtle. Although the rings can be traced on the edge detection view (Figure 1), they have very little displacement. This area could be regarded as a transitional zone between the western and eastern deformation styles.

We currently know little of the southern sector of the Silverpit structure - the Top Chalk is locally removed by erosion, and there are gaps in the existing 3D seismic coverage. Thus it is not possible to determine if there is another transitional zone in the south or south-east.

Our working hypothesis to account for the ring deformation involves lateral movement along a detachment zone near the base of the Chalk [1]. In the Silverpit area the Chalk is of variable thickness, with thicker Chalk to the east. So at the time of impact, the detachment zone had a palaeo-slope to the east, and we believe that the terrace areas defined by the concentric rings slid eastwards as a whole in a detachment tectonic style [6], in addition to the localized trough (graben) and ridge (fold) structuration. This combination of ring development and gravity slip led to systematic map view variation in ring structural style (Figure 5).

Conclusions: High-resolution 3D seismic data affords a unique opportunity to analyse in detail a well-preserved multi-ringed impact structure. A better understanding of the processes involved in creating the Silverpit structure should offer insights into the genesis of similar structures elsewhere in the solar system.

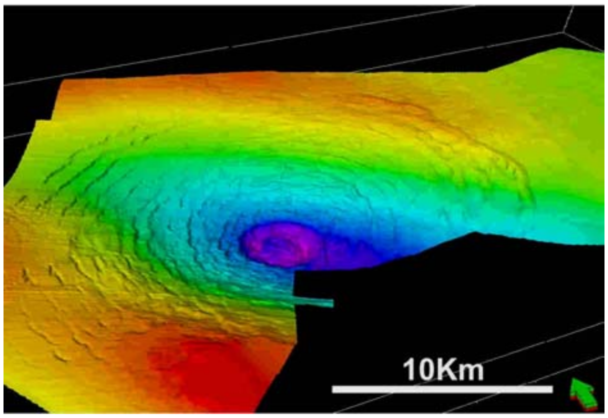

Figure 5: Perspective view of the Top Chalk showing the variable morphology of the deformation rings (left: troughs; right: ridges)

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