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Overview of the Key Structural Tools for Seismic Interpretation and Structural Model QC

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ABSTRACT

This session addresses “Key” Structural Tools for Seismic Interpretation and Structural Model QC. Nowadays, the tendency is often to think almost exclusively about software applications when tools are mentioned. However, at best, software applications only use rules and concepts which have been developed and programmed by generations of geoscientists (e.g. geologists, seismic interpreters, geophysicists etc.) in the petroleum and mining industries as well as in academia. In order to be able to use the software tools properly, it is essential to understand the relevant geological concepts on which the software applications are based. Harding and Lowell in 1979 proposed the following statement to define Structural Styles: “Broadly interrelated assemblages of geologic structures, folds and faults, constitute the fundamental structural styles of petroleum provinces”. This means that it should be possible to unravel structural styles from map views and cross sections as well as from overall 3D geometries of fault and fold frameworks. Numerous analogue sandbox modelling studies have been carried out to define the geometrical characteristics of various structural styles and associated fabrics within different structural contexts and lithology assemblages. Because they provide a link between the deformation kinematics, the rock rheology and the structural styles, sandbox studies can be considered as one of the fundamental tools. During this talk, the use of sandbox models will be discussed through key examples with direct application to the Middle East. We will discuss the importance of “knowing what to look for” both in terms of seismic interpretation as well as in term of model and interpretation QC. Let us consider first, for example, what faults look like in cross section. The Andersonian geometries can be used in brittle rocks as a first approximation. In plane strain extension or compression, conjugate sets of normal faults or reverse faults tend to dip around 60º and 30º respectively. In strike slip, faults are often near vertical, forming conjugate sets in map view. Therefore, when interpreting (or “quality controlling”) faults, checking the fault geometries on simple 1 to 1 sections (sections without vertical exaggeration) enable to make sure that the fault geometries honour the fault dips for a given structural setting. A good approach is to sketch the geological concepts, being interpreted or modelled, and to compare these with the interpretations and the resulting models. In the case of structurally complex settings, line balancing can be used to check whether the sections are restorable. This is particularly critical in compressional provinces. In map view, faults are in general organised in patterns (forming kinematic indicators) from which it should may be possible to unravel the stress regime under which the deformation took place, as well as the orientation of principal stresses at the time of deformation. Where it is not possible to recognise a typical structural style in map view, this is often a good indication that there is something wrong with the interpretation or the model. We will discuss typical classes of fault patterns characteristic of particular stress regimes. All fault dimensions are interdependent. Isolated fault planes can be assumed to have in the simplest case the shape of an ellipse, with the maximum throw towards the centre. Their long axis should be oriented along the fault strike direction. Fault throw usually decreases radially from the centre of a fault plane to reach a zero throw value at the fault tip line (unless cut by another fault). As a first approximation, we might propose as a rule of thumb that “faults are two to four times longer than high”. In case of contrasted mechanical stratigraphy, the faults have the tendency to be longer. Faults can also be shorter is case of numerous interactions with other fault sets (cross-cutting relationships). We might also consider as a first approximation that “Length divided by maximum throw is between 10 and 100 for normal faults”. Smaller values might indicate that the fault length has been

under-interpreted (unless the faults are cut by others). Larger values might indicate that the fault length has been over-interpreted or that their geometry has been over-simplified by linking individual fault segments, or that the faults may have recently coalesced or may represent growth faults emerging at a depositional surface. Once flagged, it is important to go back to the interpretation and check whether the simplification fits the model objectives as well as whether it has an impact and whether we need to do something about it. At this stage, the interpretation may need to be modified. The concept of fault throw gradient preservation along strike is also often used to check whether faults have been interpreted and modelled properly. Strong fault throw gradient variations along strike might for example indicate that a branching fault is missing. The observed fault patterns are directly controlled by the way the faults have initiated, grown and interacted with other neighbouring faults. Fault growth and coalescence has been a hot topic of research in both the petroleum industry and academia in the 80s and 90s. Faults initiate at very small scales (e.g. proto-faults initiate at grain-or crystal-sized stress anomalies), grow in length and throw, interact and coalesce with neighbouring faults. They accommodate throw and increase in length slightly and the mechanism is repeated at all scales successively. As result, faults are often composed of many coalesced segments which may be important to recognise and honour for our business decisions.
Kinks identified along fault strike and sudden fault dip changes in cross sections might indicate the presence of fault relays. These kinks should be investigated to check their presence and the nature of the relays (i.e. breached or intact). Many dry wells or improper analyses of reservoir compartmentalisation have been the result of the inability to recognise the presence of intact relays which had been oversimplified and interpreted as single continuous fault. As a result of the fault growth and propagation processes, there are many smaller faults than large faults in nature. The distribution of larger faults might be tentatively used to predict the geometry and the distribution of the under-sampled smaller faults. The fractal dimensions of fault populations have been used to predict the number and distribution of sub-seismic faults. However, these techniques (extremely fashionable in the 80's and 90's) need to be used with great caution because they can easily lead to erroneous results.

In conclusion, this presentation will cover some of the fundamental aspects of structural styles, fault growth and fault geometries. From these, we can deduce rules and techniques that can be used to support seismic interpretation and model building, as well as detailed quality control of fault interpretation and fault framework in static models. The rest of the session will be partly dedicated to complementary sophisticated software-based tools and techniques.