Keep an eye on your basement!
It is the foundation of the overlying stratigraphy and structure.

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Summary

The influence of basement on the overlying stratigraphy and structure is axiomatic for those geoscientists who work on a regional scale. The question is not 'if', but 'how much, and where'? However, for those who work mostly at the prospect scale, it is common to lose sight of the importance of the regional perspective, and therefore to fail to consider how basement tectonics may be influencing a play.

This paper will discuss many of the ways the basement influences overlying stratigraphy and structure using case studies to support and illustrate important points. The majority of examples will be Canadian, but some international cases will be included.

Examples of basement control on shallower stratigraphy and structure

The influence of basement on the overlying stratigraphy can be separated into two broad categories:

> Case 1: Those influences attributed to the pervasive, complex interactions between basement structural grain within a terrane, and the overlying section. For example, the basement structural grain can propagate upward through the section, often all the way to the surface as in the Peace River Arch (PRA), and
> Case 2: Those influences traced to reactivated boundaries between much older basement units (geological terranes), for instance the Vulcan Suture in southern Alberta.

One view is that the influence of basement structural grain unique to each terrane is fractal in nature – that is, the structural grain observed at the regional scale can give insight into the orientation and style of structure at all scales from the core up to and beyond the seismic scale. It is therefore not only important to understand the nature of the basement structural grain is (Case 1), but also to know where it may change, and whether that boundary is important in its own right (Case 2). This paper will discuss how the basement structural grain impacts the overlying structure and stratigraphy via straightforward templating of pre-existing joints, complex reactivation of basement faults, and the profound, ongoing influence of basement-seated wrench faults.

Crystalline basement usually has a characteristic set of joints which are pervasive on a regional to continental scale. Often these basement joint orientations are reflected in near surface lineaments as mapped on remote sensing data. In the Western Canada and Williston Basins, these joint orientations strike NE and NW (although they can change character and orientation subtly from terrane to terrane). These preferred orientations strongly influence the orientation of smaller-scale fractures and faulting in the entire overlying Phanerozoic section. Examples will be shown from northern Alberta (PRA and Athabasca) and from SE Saskatchewan (Missouri Coteau). It is often unclear whether these aligned structures are through-going in depth, but certainly the presence of major basement jointing should make a geoscientist investigate the possibility of a fractal joint 'family', impacting such elements as preferred fluid movements within pools.

Reactivation of pre-existing basement faults is also an important – but complex - way the basement interacts with the overlying section. Reactivation can occur multiple times with not only a wide variety of magnitude of movement, but also with different senses of motion.

At the basinal scale, multiple orogenic events within one basin can create a complex structural fabric involving much older basement. During the younger events, new stress regimes will preferentially reactivate optimally oriented older structural faults while generating new faults that cut across other elements of the older structural fabric. Examples include inversion of pre-existing half grabens (Oriente Basin in Ecuador) and new rift geometries that partially reactivate older rift geometries (Lake Malawi, East African Rift).

Pre-existing basement structure can also have a major effect on the development of fold and thrust systems in later orogenies. In addition to the inversion structures mentioned above, there are several examples of major stratigraphic and structural variations being controlled by underlying basement faults, including the major changes in structural style on either side of the Great Slave Lake Shear Zone, and the Vulcan Suture. On a less dramatic scale near Hinton, a change in the width of the disturbed zone is coincident with a NE striking fault that gravity indicates is offset down to the NW by 100's of metres.

Where the reactivation offsets are very small, they can still express themselves with various stratigraphic signatures in the overlying section. Examples include:

- Reef growth on footwall of small scale normal faults (almost everywhere that reefs are found),
- Enhancement of reef and mud mound growth by fluid flow along faults (Winnipegosis reefs, Williston Basin),
- Accommodation of earlier structure in later sedimentation, resulting in isopach variations that are inverse to the underlying structure (Hotchkiss horst, northern Alberta),
- Subtle but pervasive control of channel orientations (Dunvegan channels, PRA),
- Facies variations related to small changes in water depth (shorelines at hinge zones controlled by underlying structure)

Understanding the structural trends of the underlying control can help predict multiple occurrences of prolific reservoirs.

Not only does basement structure imprint carbonate and clastic deposition, it can have a major influence on the behaviour of later evaporite deposits. Examples here include:

- Non deposition of salt over basement highs, resulting in areas without diapiric activity (Gulf of Mexico),
- Focus of salt diapirism by basement faults (all salt provinces where halokinesis occurs),
- Focus of later salt dissolution (Hummingbird Trough, SE Saskatchewan).

Finally, major wrench systems are a special class of basement-seated structures characterized by recurrent activity that increases in complexity upwards. These deep-rooted systems can impact structure, stratigraphy and diagenesis of the surrounding sections. The Great Slave Lake Shear Zone is one of the best documented examples of this in the world. It influences a wide variety of plays, including:

- Fracture development (Ladyfern, NEBC),
- Basin development (Rainbow-Zama, N. Alberta),
- Structural reactivation.

Wrench faults and other deep-seated faults impact surrounding sediments diagenetically as major conduits for focussing the flow of hot fluids. Hot fluids can play a local role in the thermal maturity of source rocks, but more importantly, they control the creation - or destruction – of reservoir quality. Examples include:

- Dolomitization (Hamburg, N. Alta.; Albion-Scipio, Michigan; Ghawar, Saudi Arabia, and many, many others),
- Creation and/or destruction of secondary porosity (Parkland, NEBC)
- Kimberlites (Alberta diamond play),
- Emplacement of younger sills (South China Sea, Mexico).

Conclusion

Basement structure is the foundation for the overlying stratigraphy and structure. There are many examples of subtle variations that appear, at first glance, to be random. With closer examination over a large area, the underlying cause – basement control – often becomes clear. Understanding this influence and learning to decipher it gives the explorationist the power of prediction. Prediction is one of the most critical skills for generating new plays, whether one is working in a frontier basin overseas or in a very mature basin here at home.