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Sequence Stratigraphy – an emerging tool in hydrogeologic investigations

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Summary

It is well known that regional and local differences in sediment supply, depositional environment, and tectonics affect the development of aquifers. Sequence stratigraphy and facies models provide a predictive framework for these aquifer units. Sequence stratigraphy allows packages of sands to be bracketed in a predictable manner by confining units. Facies analysis allows prediction of the potential scale and connectivity of sands, with a dimension of scale increasing from tens of meters in fluvial environments to hundreds of kilometers in certain marine environments. Sequence stratigraphic data analysis and facies models provides a means of predicting permeability, porosity, and hydraulic conductivity of aquifers, though precise estimates of these parameter and aquifer yields can only be done through hydraulic testing. Further, understanding the sequence stratigraphy and depositional facies are critical for understanding scale and connectivity of aquifers and their confining units and predicting their local and regional distributions. In a sense, sequence stratigraphic data analysis/interpretation has hidden potential which can be utilized for aquifer exploration and exploitation.

Introduction

Sequence stratigraphy has long provided predictions about petroleum reservoirs and impermeable caps and has potential for similar applications in groundwater predictions. Since the advent of its use for basin scale petroleum exploration in the 1970s, sequence stratigraphy has evolved into an important tool for finer-scale stratigraphic problems in industry such as reservoir geology. Hydrogeologic investigations are confronted with challenges similar to those in petroleum geology such as delineating the fine scale stratigraphy of aquifers (akin to reservoirs) and confining units (akin to traps). This paper attempts to analyse few of the potential application of sequence stratigraphic principles to ground water hydrology.

Theory

The low stand systems tract (LST) is the set of depositional systems active during the time of relatively low sea level following the formation of the sequence boundary. If a distinct shelf-slope break exists and relative sea level has fallen sufficiently, the low stand systems tract may include two distinct parts, the low stand fan and the low stand wedge. The low stand fan consists of a basin-floor submarine fan. This fan often contains a series of feeder channels as well as distinct fan lobes. The low stand fan typically displays aggradational stacking and is overlain by the low stand wedge. During the time of lowest relative sea levels on siliciclastic margins, rivers begin to incise into the exposed shelf and this sediment is shunted directly off the shelf edge to feed submarine fans. The most prominent example of buried

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valleys hosting productive aquifers, are incised valleys (Fig.-1). Sandstone bodies associated with incised valleys are prolific aquifers.

The sequence stratigraphic setting and environment of deposition are critical for predicting continuity of aquifer units. Sands and overlying confining units may be continuous on various scales from tens of meters to over hundreds of kilometers, yet sequence stratigraphic and facies analysis provides confidence that certain aquifers and confining units are continuous on scales of tens of kilometers. Aquifer sands deposited in marine shelf environments tend to be continuous on the kilometer scale. Confining beds for these units can be typically shelf or prodelta silty clays that are even more laterally continuous.

Aquifers in the coastal plain vary from localized sand bodies to regional sand sheets associated with the upper part of high stand system tracts (HST). The extent of sand vs. mud can be strongly influenced by the proximity of the sand sheets to sources. Extensive sand bodies of tens to hundreds of kilometers scale can develop on continental shelves or in delta fronts as part of upper HST sands. The widespread nature of aquifer sands can be attributed to their deposition in a delta front environment.

Although the sequence stratigraphy methodology offers many advantages, most hydrogeological models still use the litho correlation methodology to determine aquifer geometries. However, whereas, litho correlation may not assume any dip of sand bodies towards basin, the chrono stratigraphic correlation is based on basin ward dipping clinoforms thereby predicting the geometry of aquifers more accurately (Fig.-2).

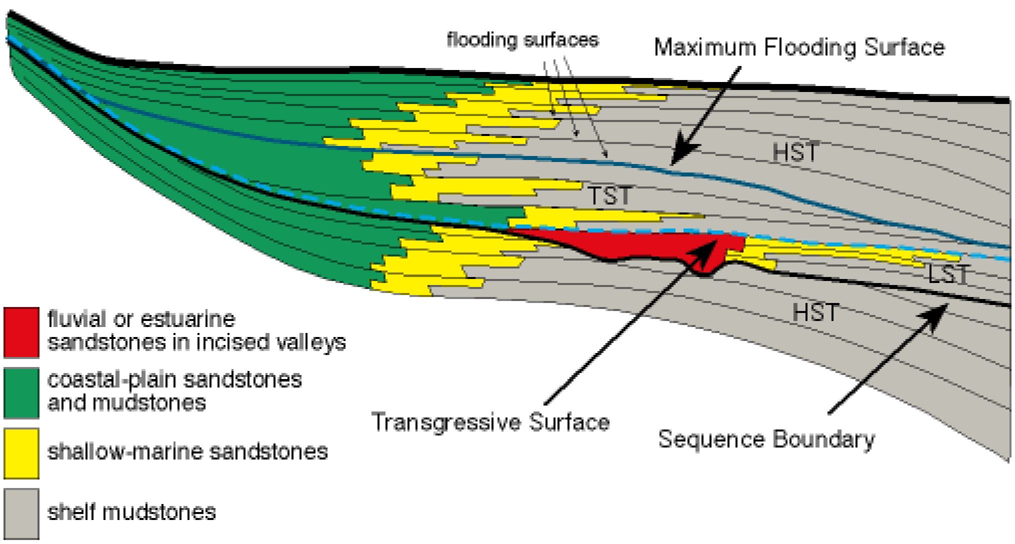

Fig.-1: Typical LST showing incised valleys - adapted from Van Wagoner et al. (1990)

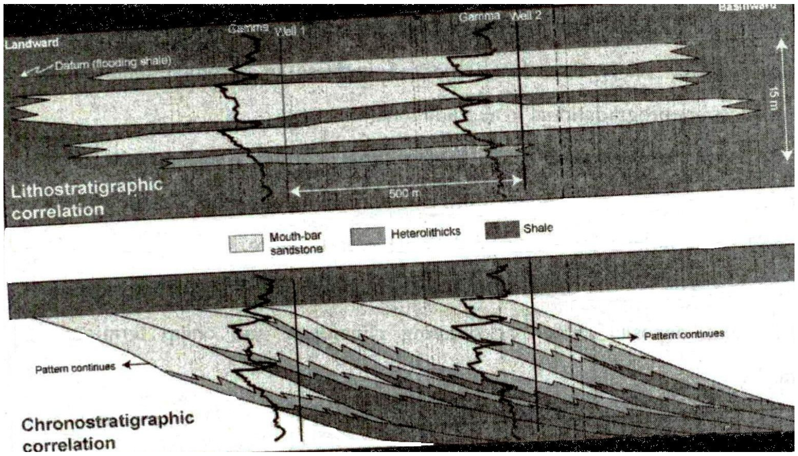

Fig.-2: Subsurface model of well log correlation along depositional dip (From Gani and Bhattacharya, 2006)

Conclusion

It may be concluded that in addition to the multifaceted applications of sequence stratigraphhy in oil industry, it has untapped potential for aquifer exploration and exploitation. This hydrogeologic application of geo data needs to be further investigated in view of its enormous potential to refine/fine tune exploration and exploitation/development of fresh water aquifers, another emerging strategic natural resource, after oil in near future.

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