Multicomponent Seismic Detection and Interpretation of Salt and Salt Dissolution

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INTRODUCTION

Geophysical expressions of salt and salt dissolution are extremely significant for the explorationist for a number of reasons; salt dissolution may develop and affect hydrocarbon traps in the following ways: 1) reservoir facies can be structurally closed over the edges of residual salt bodies (Figure 1), or over salt remnants as a result of progressive leaching of salt (Figure 2); 2) reservoir facies can be stratigraphically trapped where preferentially deposited in salt-dissolution lows (Figure 3) or highs; 3) reservior facies can be stratigraphically trapped where preferentially preserved in a salt-dissolution low (Figure 4); 4) drape across a salt remnant can be misinterpreted on seismic data as either drape across a reef or as being indicative of basement anticlinal structure, for example Wabamun salt and Leduc reef (see Figure 5); 5) salt can either enhance or degrade the seismic signature of an underlying reef (see Figure 6); 6) a low-velocity salt interval can be misinterpreted as a porous reservoir (for example, Wabamun salt and Nisku porosity); 7) salt dissolution usually causes brecciated and faulted zones which can allow oil to leak out of potential traps.

The objectives of this study are to gain an understanding of salt and salt dissolution features, to develop the capability to indentify salt and salt dissolution on conventional and multicomponent seismic sections and in gravity data, and to undertake the analysis and interpretation of such a geophysical dataset.

This paper constitutes an M.Sc. thesis proposal to be carried out by the first author under the supervision of the second author. The specific area of investigation will depend on the seismic and gravity data available.

SALT DISSOLUTION AND ITS GEOPHYSICAL MANIFESTATIONS

Features related to dissolution of salt include: collapse, like the Hummingbird structure (Smith and Pullin, 1967); linear features related to elongate and salt-wall structures associated with faulting; widespread, relatively uniform subsidence of the overburden accompanied by blanket brecciation, caused by areal salt dissolution; and edge dissolution effects at the periphery of a salt basin or unconformity. The fresh-water sources that initiate salt dissolution could be meteoric water; water from conversion of gypsum to anhydrite; or water from shale compaction (Sun, 1990). A circulatory system which has means of ingress and egress for fresh water usually is provided by basement reactivation. Timing and extent of salt leaching is important as both structural and stratigraphic traps can form as a result.

It has been seen that salt has special properties (Gardner et al., 1974; Pickett, 1963). It has relatively low density, high velocity, its density variations are small, and the ratio of shear-wave (S-wave) velocity to compressional-wave (P-wave) velocity is low (around 0.5). The P-wave velocity is around 4.5 km/s (see Figures 8 & 9). The ratio of S-

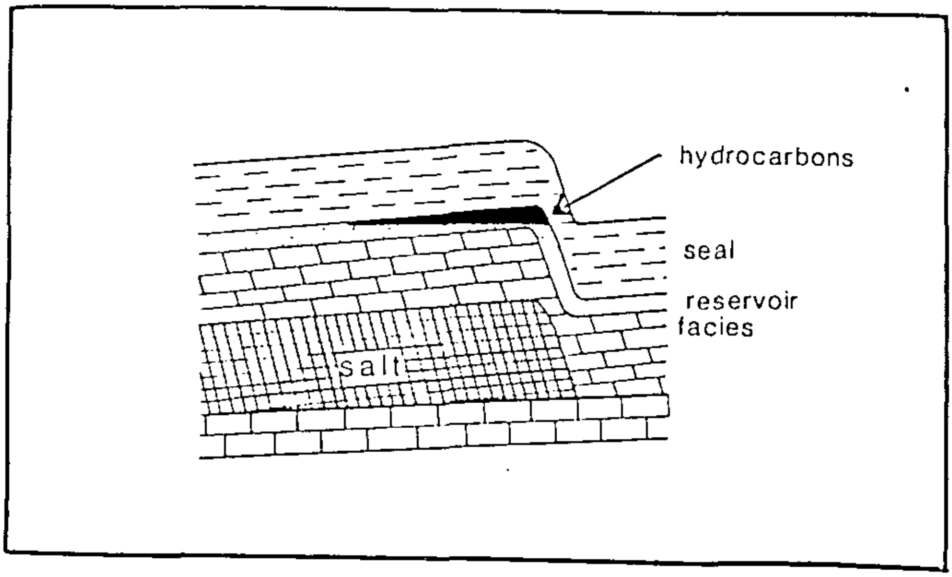

Fig. 1. Reservoir facies structurally closed across the edge of a salt remnant due to salt dissolution.

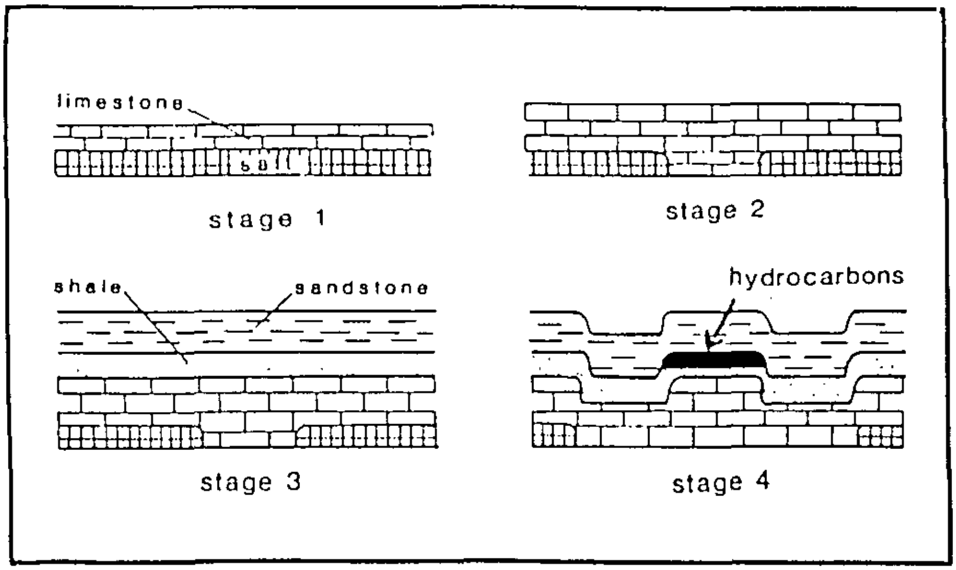

Fig. 2. Reservoir facies structurally closed over a salt remnant as a result of progressive leaching of salt.

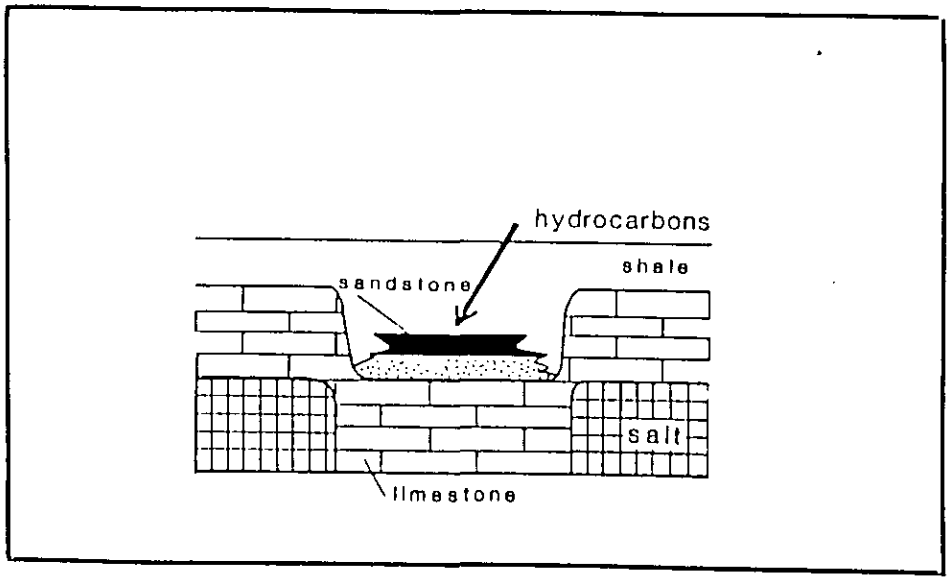

Fig. 3. Reservoir facies preferentially deposited within a salt-dissolution low.

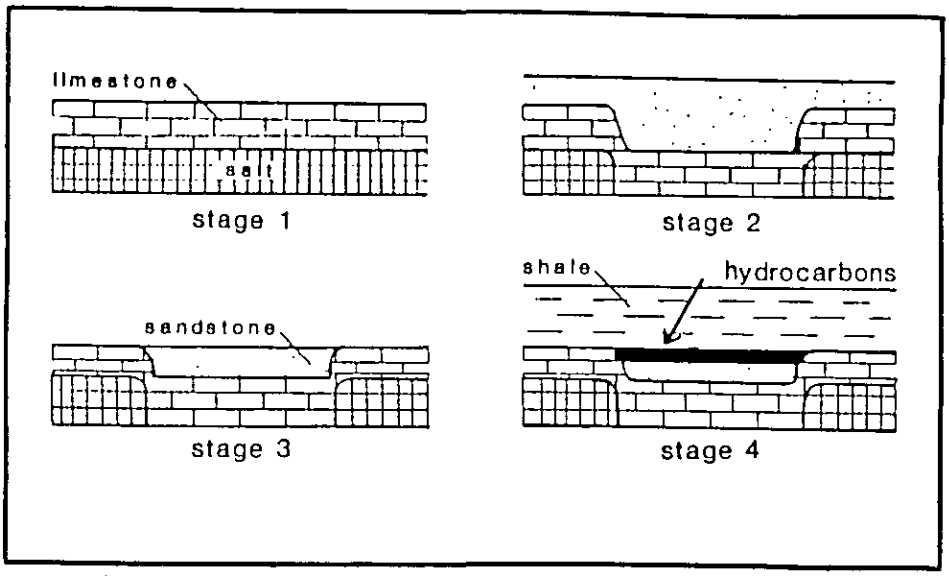

Fig. 4. Reservoir facies preferentially preserved in a salt-dissolution low.

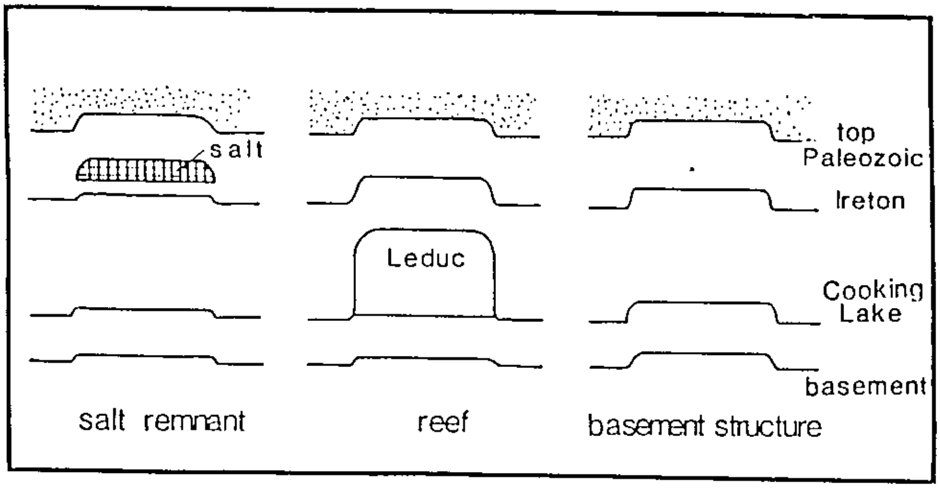

Fig. 5. A salt remnant misinterpreted as either reef or basement structure.

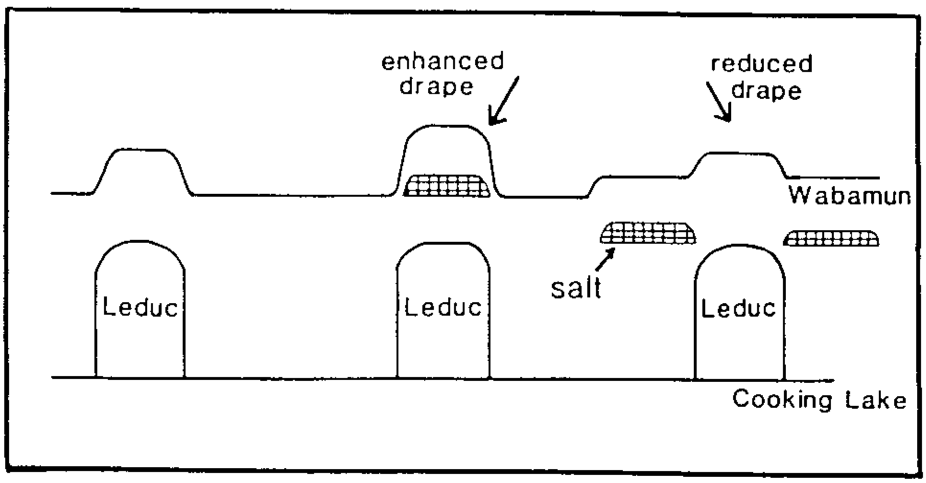

Fig. 6. Enhanced and reduced drape due to salt dissolution.

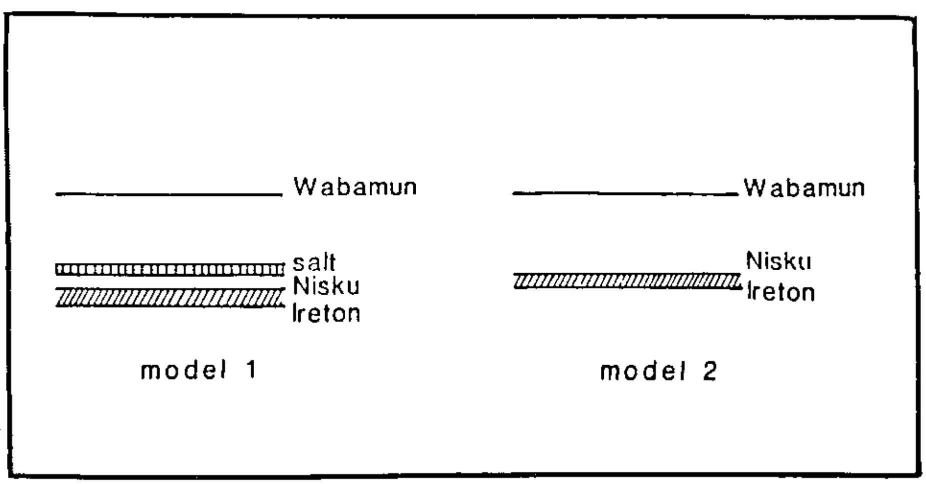

Fig. 7. The relatively low-velocity Wabamun salts misinterpreted as porosity within the Nisku Formation.

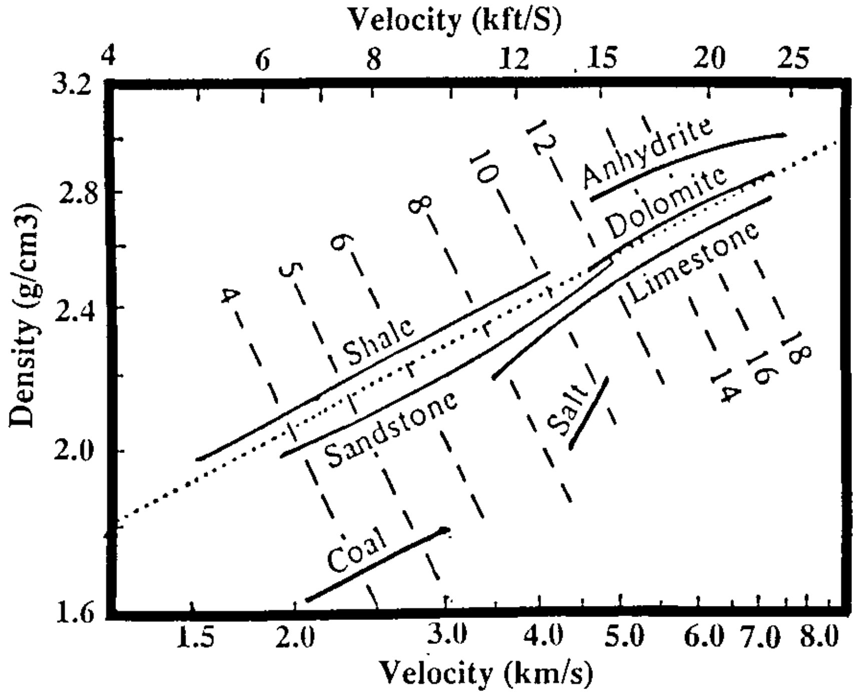

Fig. 8. P-wave velocity-density relationship for different lithologies; log-log scale (after Gardner et al., 1974).

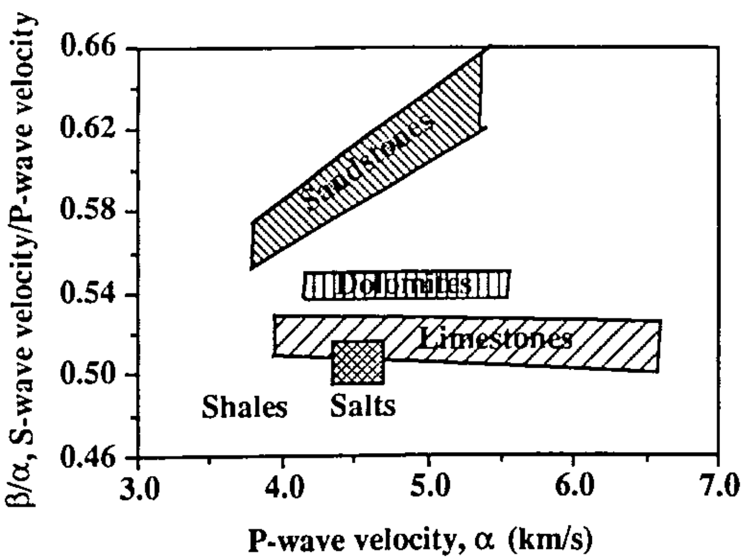

Fig. 9. β/α vs α for different lithologies (After Pickett, 1963);

wave velocity to P-wave velocity can be obtained through traveltime measurement on P-wave and S-wave sections. However, salt could conceivably have the same value of S- and P-wave velocity as limestone. Also a salt remnant could be mistakenly considered as a reef (as mentioned above) on a seismic section, and vice versa. But if we are aware of the density difference between them, it is possible to use gravity data to detect salt. Anderson et al. (1988) pointed out that salts generate negative anomalies on gravity data due to their low density. However, almost all reefs generate positive gravity anomalies (Yungul, 1961; Gretener, 1969).

RESEARCH DIRECTION AND DATA

We hope that we can develop some interpretational schemes for seismic data with salt and salt-removal features in the seismic section. Well logs will be used extensively to map salt distribution, collapse features, etc. We are also going to incorporate gravity data with seismic data in the interpretation where possible to examine its usefulness, and to investigate whether three-component data and P- and S-wave sections can provide additional useful information, perhaps in terms of a distinctive P-to-S velocity ratio, or of anisotropic effects (stress-induced?) such as shear-wave splitting. In any case, we have extensive conventional seismic data available in a large area of southern Alberta which will be used to correlate between well control points and to fill in a more continuous picture of subsurface salt distribution and overlying structure.

ACKNOWLEDGEMENT

The first author (Z.S.) gratefully acknowledges the support recieved from the CREWES Project in the form of a student assistantship.

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