EHRENBERG, STEPHEN N., Statoil, N-4035 Stavanger, Norway, sne@statoil.com;
GREGOR P. EBERLI, Comparative Sedimentology Laboratory, Univ. of Miami, USA;
MOHAMED KARAMATI, Research Institute of Petroleum Industry, Tehran, Iran; and
ALI MOALLEMI, Research Institute of Petroleum Industry, Tehran, Iran

Porosity Differentiation within Interbedded Limestone - Dolostone Reservoirs

We observe that interbedded limestones and dolostones in 3 deeply buried carbonate platforms have very different porosity frequency distributions, with the limestones being tighter and asymmetrically "heaped" against the limit of zero porosity. Comparison with data from younger, shallowly buried carbonates suggests that this contrast originated mainly due to the greater resistance of dolostones to chemical compaction and burial cementation.

Dolostones seem to be widely regarded as in general having better reservoir properties than limestones. However, few studies have been published that quantitatively compare limestones and dolostones within individual stratigraphic units. We present a large compilation of such data and examine the implications for models describing carbonate porosity evolution in response to burial diagenesis. Most samples in each dataset can be readily classed as either limestone or dolostone, with partly dolomitized samples being generally subordinate. On the local scale, therefore, it appears that dolomitization in these strata tended to run to completion once it had begun.

Porosity frequency distributions, from core-plug measurements, have been examined in five large datasets of shallow-water carbonate platform strata that consist of interbedded limestones and dolostones:

- the Madison Formation (Mississippian) in outcrop sections and cores from Wyoming and Montana, USA, maximum burial depth 3300-7500 m.
- the Finnmark carbonate platform (Pennsylvanian-Lower Permian) from exploration wells offshore north Norway. Present burial depth is 1410-1750 m, but maximum burial was probably 2400-3300 m.
- the Asmari Formation (Oligocene-Miocene) in two giant oilfields of southwest Iran, burial depth 1660-3700 m.
- Great Bahama Bank (Late Miocene-Pleistocene) from boreholes Unda and Clino, burial depth 33-670 m.
- Marion Plateau (Miocene) offshore NE Australia, ODP Leg 194, burial depth 0-650 m.

In the deeply buried strata (Madison, Finnmark, Asmari), the limestones have positively skewed porosity distributions with highest frequency of values, or "mode", in the range 0-5%, whereas dolostones have more symmetrical distributions with the mode around 8-15% and relatively few values <5% (Figs. 1-4). The tight limestones form laterally extensive flow barriers that divide the formations into thin stratigraphic compartments. Understanding the diagenetic processes controlling this porosity differentiation is therefore fundamental to building models of fluid displacement.

The tight limestones display both parasequence and sequence scales of clustering, and there is strong porosity partitioning between transgressive and regressive hemicycles. However, both the polarity of this partitioning (whether tops or bases of cycles are porous) and the facies involved vary depending on position within both platform paleogeography and lower-order system tracts.

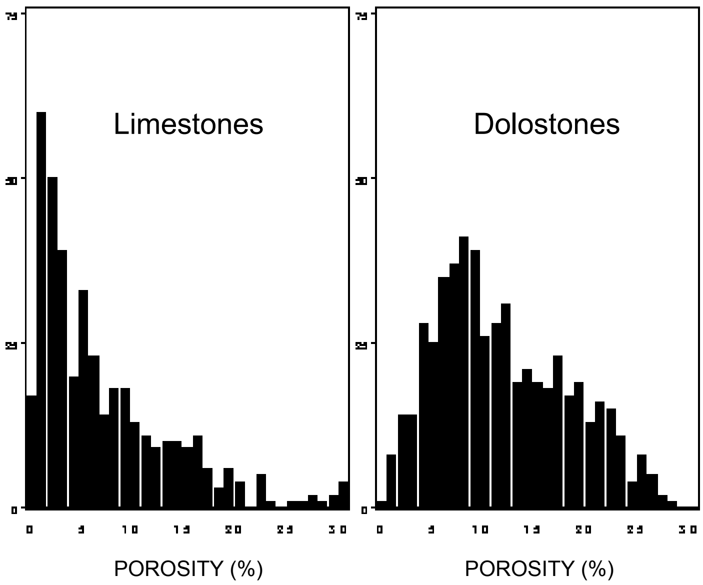

Figure 1 - Frequency distribution of plug porosity measurements in outcrops and cores of the Madison Formation (Mississippian, Wyoming and Montana), maximum burial depth 3300-7500 m.

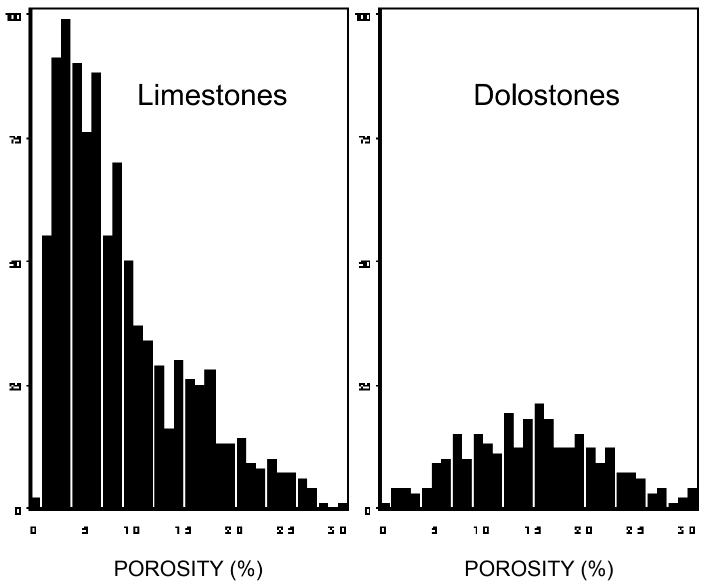

Figure 2 - Frequency distribution of plug porosity measurements in cores from the Finnmark platform (Gipsdalen Group, Pennsylvanian-Lower Permian, offshore north Norway), maximum burial depth 2400-3300 m.

The tight limestones of the deeply buried strata correspond with both: (1) muddy facies that have lost porosity by early matrix compaction and cementation, and (2) grainy facies that have lost porosity by calcite cementation. Geochemical data for the Finnmark platform indicate that cementation of the grain-dominated limestones was a burial phenomenon related to chemical compaction along stylolites, a process believed to be activated by increasing temperature. Intensity of cementation is proportional to abundance and proximity of stylolites. Thus, reservoir compartmentalization by tight limestone barriers may occur to a large degree relatively late in the burial history. If so, this is a fundamental difference from quartzose sandstone reservoirs, where barriers are mainly formed by shaly layers present from the time of deposition and where quartz cementation (also a temperature-dependent burial process related to stylolitization) tends to result in more uniform porosity loss throughout the reservoir interval.

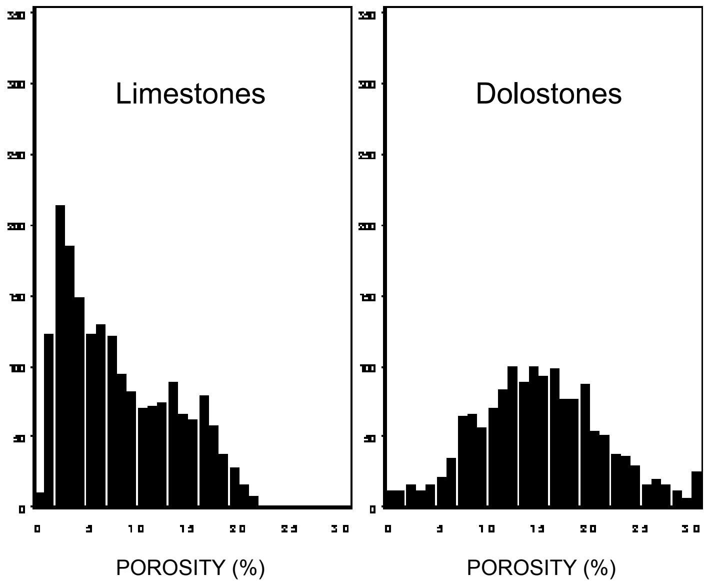

Figure 3 - Frequency distribution of plug porosity measurements in cores from the Asmari Formation in Bibi Hakimeh Field (Oligocene-Miocene, Iran), burial depth 1660-2130 m.

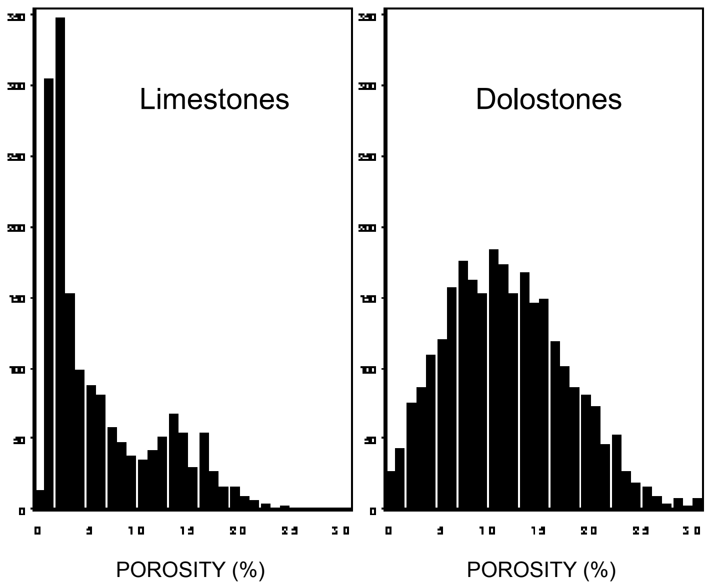

Figure 4 - Frequency distribution of plug porosity measurements in cores from the Asmari Formation in Marun Field (Oligocene-Miocene, Iran), burial depth 3000-3700 m.

Paucity of low porosity values in the dolostones of the three deeply buried datasets is due to the almost ubiquitous presence of intercrystalline macroporosity and common presence of moldic pores. These two types of secondary porosity are interpreted as being largely of near-surface origin, possibly created and enhanced by early dissolution of remaining calcite in partly dolomitized beds. Their preservation during burial reflects the greater resistance of dolostone to chemical compaction and resulting cementation.

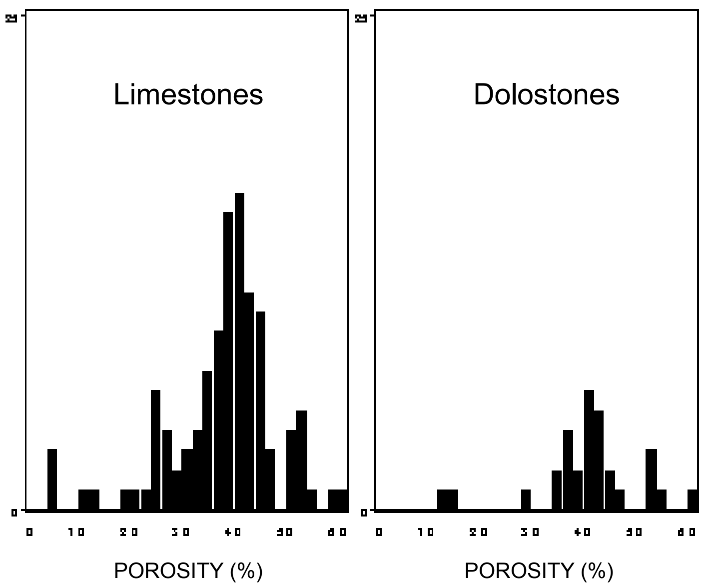

Figure 5 - Frequency distribution of plug porosity measurements in cores from Great Bahama Bank (Late Miocene-Pleistocene; boreholes Unda and Clino), burial depth 33-670 m.

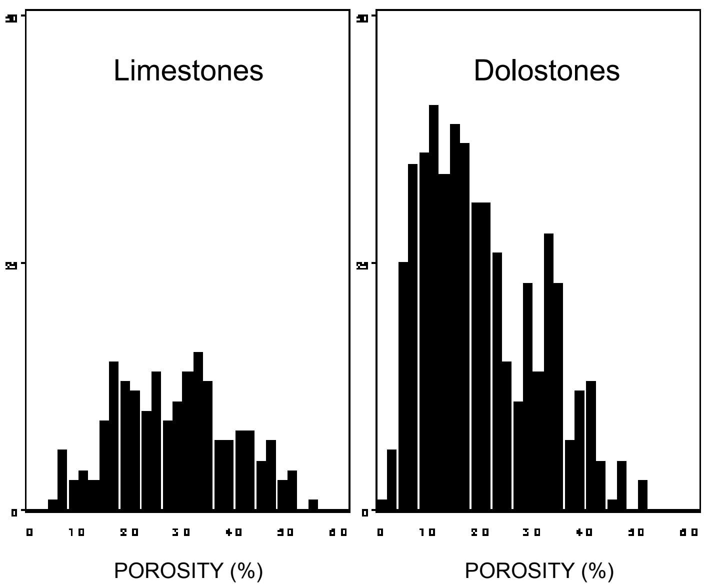

Figure 6 - Frequency distribution of plug porosity measurements in cores from carbonate platforms of the Marion Plateau (Miocene; ODP Leg 194, Sites 1193, 1196, and 1199), burial depth 0-650 m.

Porosity-permeability datasets from younger carbonate platforms buried less than one kilometer (Bahamas and Marion Plateau; Figs. 5 and 6) do not show differences between limestone and dolostone porosity distributions similar to the deeply buried strata. The Marion Plateau carbonates in fact show the opposite tendency, that is, overall lower porosities and positive skewness in the dolostones. This contrast tends to support a late diagenetic timing for porosity loss in limestones of the deeply buried strata, which have experienced significantly higher temperatures during longer and deeper burial histories.