Rudists Reservoir Characterization in Middle Cretaceous Mishrif Formation of H Oilfield, Iraq*

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Search and Discovery Article #20336 (2016)
Posted January 18, 2016

*Adapted from extended abstract prepared in conjunction with oral presentation at AAPG/SEG International Conference & Exhibition, Melbourne, Australia, September 13-16, 2015, AAPG/SEG © 2016.

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Abstract

Extinct rudists are one of the most typical characteristics of the Cretaceous, which is the main reservoir of the Middle Cretaceous Mishrif Formation, Halfaya Oil Field, Iraq. The principle sedimentary facies of Mishrif Formation was a rimmed platform, in which the platform margin rudists shoal/reef were the favorable sedimentary settings. The main lithofacies in Mishrif Formation are rudists reef limestone, coexisted coral reef limestone, sponge reef limestone, algal reef limestone and reef breccias. The best reservoir conditions in the Mishrif Formation occur in rudist-bearing facies, such as rudstones and rudistid packstone/grainstones. Reservoir units are characterized by porosities of >20% and by permeabilities of 100 mD to 1 Darcy. Other carbonate facies, such as pelagic mudstone/wackestones, bioclastic wackestones and peloidal packstones, are less significant as reservoir rocks. All the carbonates were affected by a range of diagenetic processes, among which dissolution and dolomitization led to the formation of secondary porosity; porosity was reduced by compaction, stylolitization, micritisation, neomorphism and cementation. Topmost of the Mishrif Formation (same as the boundary of Middle to Late Cretaceous) is an obvious unconformity, which caused the fabric-selective meteoric dissolution in rudists of Mishrif Formation. The Mishrif Formation is divisible by a prominent unconformity into two large-scale regressive sequences, which are particularly distinguishable in the east of the Mesopotamian Basin. Because the aragonite shells of rudists are easy to dissolve, there is positive correlation between the aragonite contents and the porosity of rudists in Halfaya Oil Field. Five main pore types related to rudists were distinguished: (a) inter-grain/inter-breccia pores, (b) framework pores, (c) vuggy intraskeletal and biomoldic pores, (d) dissolution pores, and (e) caverns.

Introduction

One of the most typical sedimentary characteristics of the Cretaceous is tropical carbonate sedimentary strata: a representative extinct rudists bioclastic limestone (Skelton, 2003). Rudist is a kind of specialized fauna of *Bivalvia Mullusca* (Figure 1), which was extinct in the end of Cretaceous. They were mainly found in marine Cretaceous strata. The distribution areas of rudists are in Tethys regions (as far north as south Sweden and as far south as Madagascar which is equivalent to modern North Latitude 55° to South Latitude 20°) (Figure 2). Globally, there have been seven families, more than 100 generals and hundreds of species that were described (Gou, 1995). The extinct rudists in the

Cretaceous was the only time in geological history that bivalves could build reefs, which is the main reservoir of Middle Cretaceous Mishrif Formation in H Oilfield, Iraq.

Introduction of Middle Cretaceous Mishrif Formation

The Cenomanian-early Turonian Mishrif Formation reservoir of the Mesopotamian Basin accommodates more than one third of the proven Iraqi oil reserves within rudist-bearing stratigraphic units. Extensive accumulation of rudist banks occurred along an exterior shelf margin of the basin along an axis that runs from Hamrin to Badra and southeast of that, with interior margins around an intrashelf basin. Buildups were stacked or sometimes shingled as thicker shallowing-up cycles of several smaller-scale accommodation cycles. As a result, each field shows different combinations of pay zones, barriers and seal geometries.

The Mishrif Formation has a gradational contact with the underlying Rumaila Formation but is unconformably overlain by the Khasib Formation. The allochems in the Mishrif Formation are dominated by bioclasts, whereas peloids, ooids, and intraclasts are less abundant. The sedimentary microfacies of the Mishrif Formation includes mudstone, wackestone, packstone, grainstone, floatstone, and rudstone, which have been deposited in basinal, outer shelf, slop followed by shoal reef and lagoonal environments. The formation displays various extents of dolomitization and is cemented by calcite and dolomite. The principle sedimentary facies of Mishrif Formation was a rimmed platform, in which the platform margin rudists shoal/reef was the favorable sedimentary settings. The main lithofacies in Mishrif Formation are rudists reef limestone, coexisted coral reef limestone, sponge reef limestone, algal reef limestone and reef breccias.

The best reservoir conditions in the Mishrif Formation occurred in rudist-bearing carbonates, such as rudstones and rudistid packstone/grainstones. Reservoir units are characterized by porosities of >20% and by permeabilities of 100 mD to 1 Darcy. Other carbonate facies, such as pelagic mudstone/ wackestones, bioclastic wackestones and peloidal packstones, are less significant as reservoir rocks.

Main Reservoir Characterization of Middle Cretaceous Mishrif Formation

Five kinds of main pore types related to rudists were distinguished:

- Framework dissolution pores: after the sedimentary of rudists, the soft part of rudists decayed to form pores and some of the shell minerals heterogeneously dissolved to form pores (Figure 3, a, b).
- Intergrain / inter-breccia pores: the rudists breccias and other reef breccias re-deposited, in which there were abundant pores (Figure 3c).
- Vuggy intraskeletal and biomoldic pores (Figure 3d).
- Dissolution pores (Figure 3, a, b, c).
- Caverns (Figure 3c).

Origin of Rudists Reservoirs

The sequence stratigraphic analysis led to three complete 3rd order sequences being distinguished. Eustatic sea level changes controlled development of the sequence stratigraphy. Tectonism primarily defined the sites of platform development that complicated the architectural heterogeneity of the depositional sequences. Topmost of the Mishrif Formation (same as the boundary of Middle to Late Cretaceous) is an obvious unconformity, which caused the fabric-selective meteoric dissolution in rudists of Mishrif Formation.

A porosity-predictive model, employing sequence stratigraphic concepts, shows porosity increasing beneath sequence boundaries due to meteoric dissolution and karstification, whilst rising sea level induces dolomitization on the platform, causing porosity enhancement at early TST. Porous rudist facies usually coincide with the crestal areas of many fields in the region, particularly in those anticlines, which show evidence of synsedimentary structural growth. However, other structures have also proven to be non-productive on their crests because of the presence of tight or microporous offshore facies instead of rudist-bearing reservoir facies. Occurrences of interconnected vuggy pores of grain-dominated fabric in the grainy facies make them the best reservoir units. Dissolution of the aragonitic components of rudist shells was the most important diagenetic process that enhanced reservoir characteristics. There is positive correlation between the aragonite contents and the porosity of rudists in H Oilfield (Figure 4).

Presence of rudist-bearing facies with their diagenetic effects within highstand systems tracts is considered the primary factor in effective porosity development and distribution. All the carbonates were affected by a range of diagenetic processes, among which dissolution and dolomitization led to the formation of secondary porosity; porosity was reduced by compaction, stylolitization, micritisation, neomorphism and cementation.

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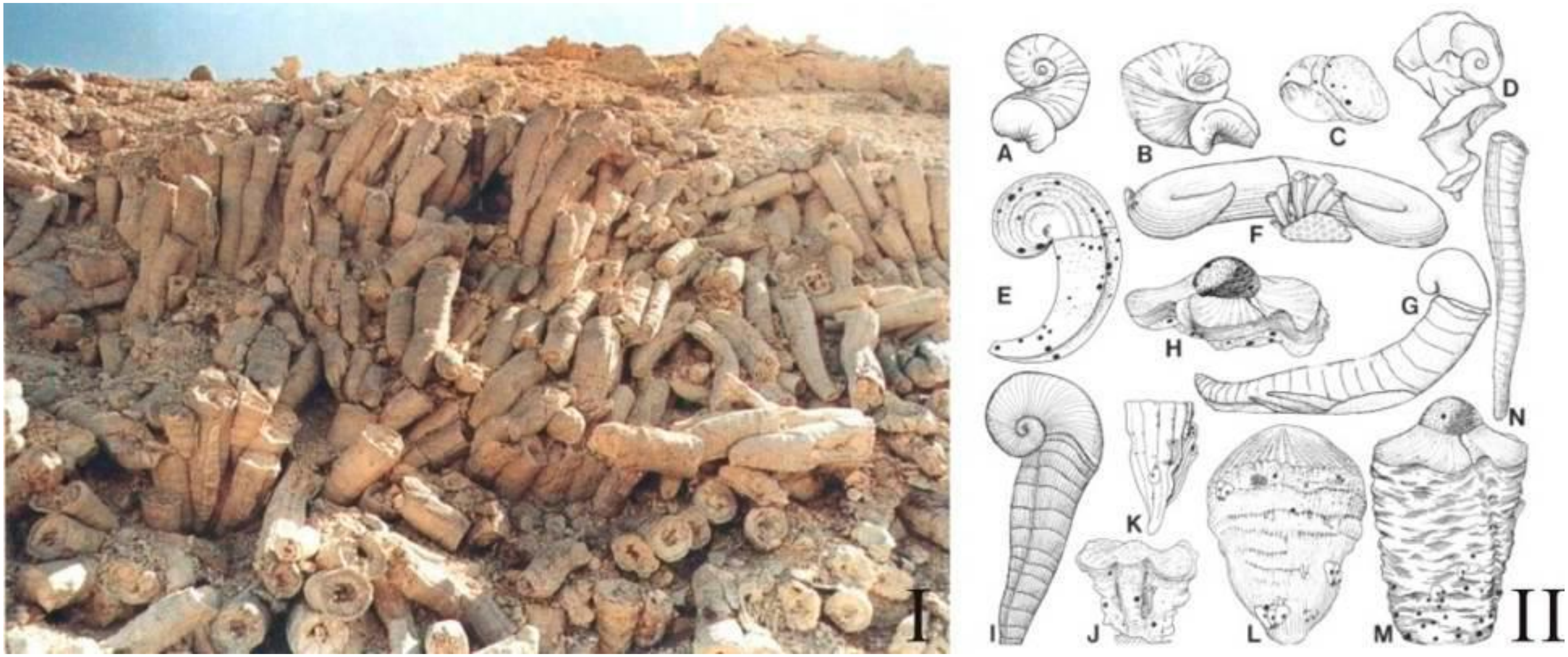


Figure 1. Rudist characteristics from outcrop and drawings.

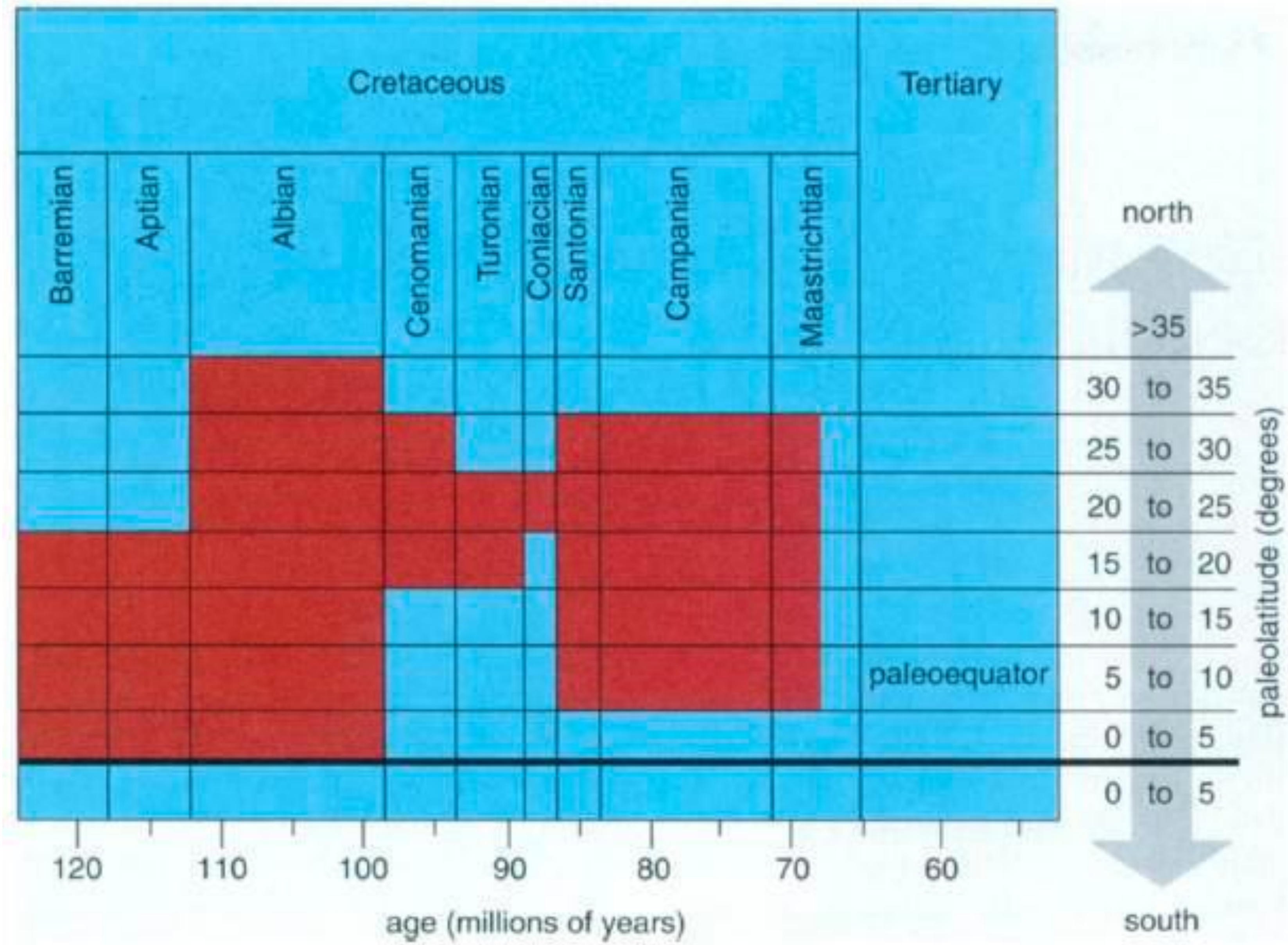
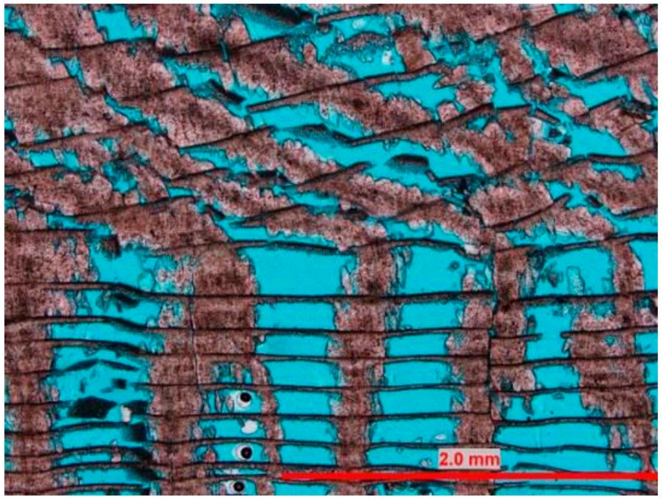
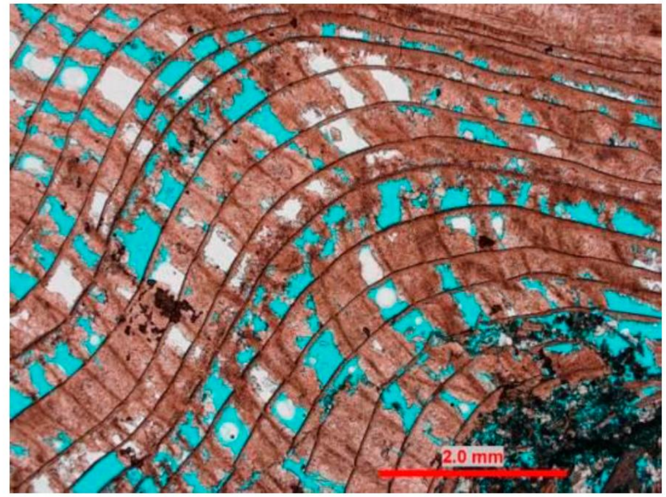


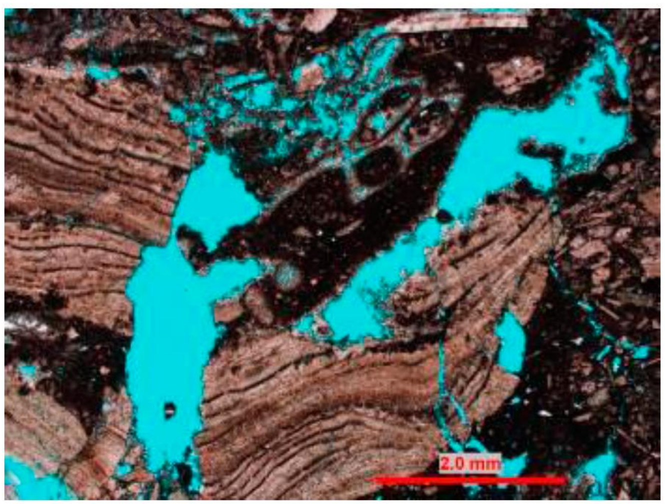
Figure 2. Fossil evidence shows that the latitude range of Caribbean rudists fluctuated during the Cretaceous period. They became comparatively restricted during the Cenomanian, Turonian and Coniacian ages, presumably because greater amounts of oceanic heat were transported away from the tropics. Geologists struggle to explain why the rudists died out before the disaster that brought the Cretaceous to an end (From Johnson, 2002).



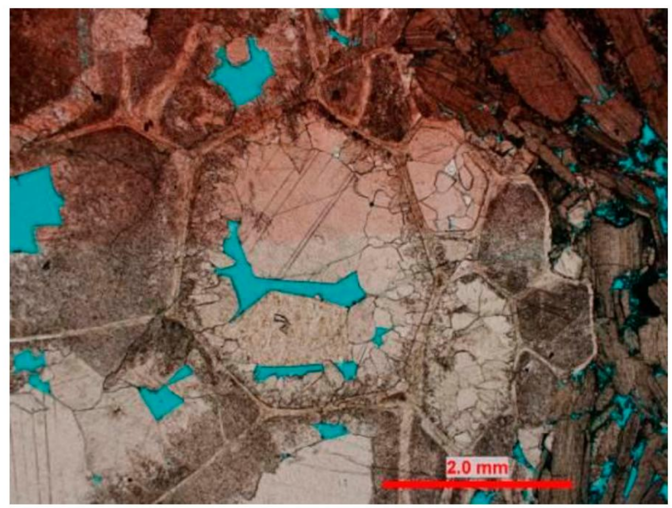
a. Framework dissolution pores in Rudist shell. PPL



b. The framework heterogeneous dissolution pores developed in Rudists shell. Some pores were partially filled by some dolomite crystals. PPL.



c. Inter-breccia dissolution pores in Rudist-bearing carbonate. PPL



d. The coelomopore of coral associated with Rudists were partially filled by sparry calcite. PPL

Figure 3. Main reservoir types related to Rudist-bearing carbonate in Mishrif Formation, H Oilfield, Iraq.

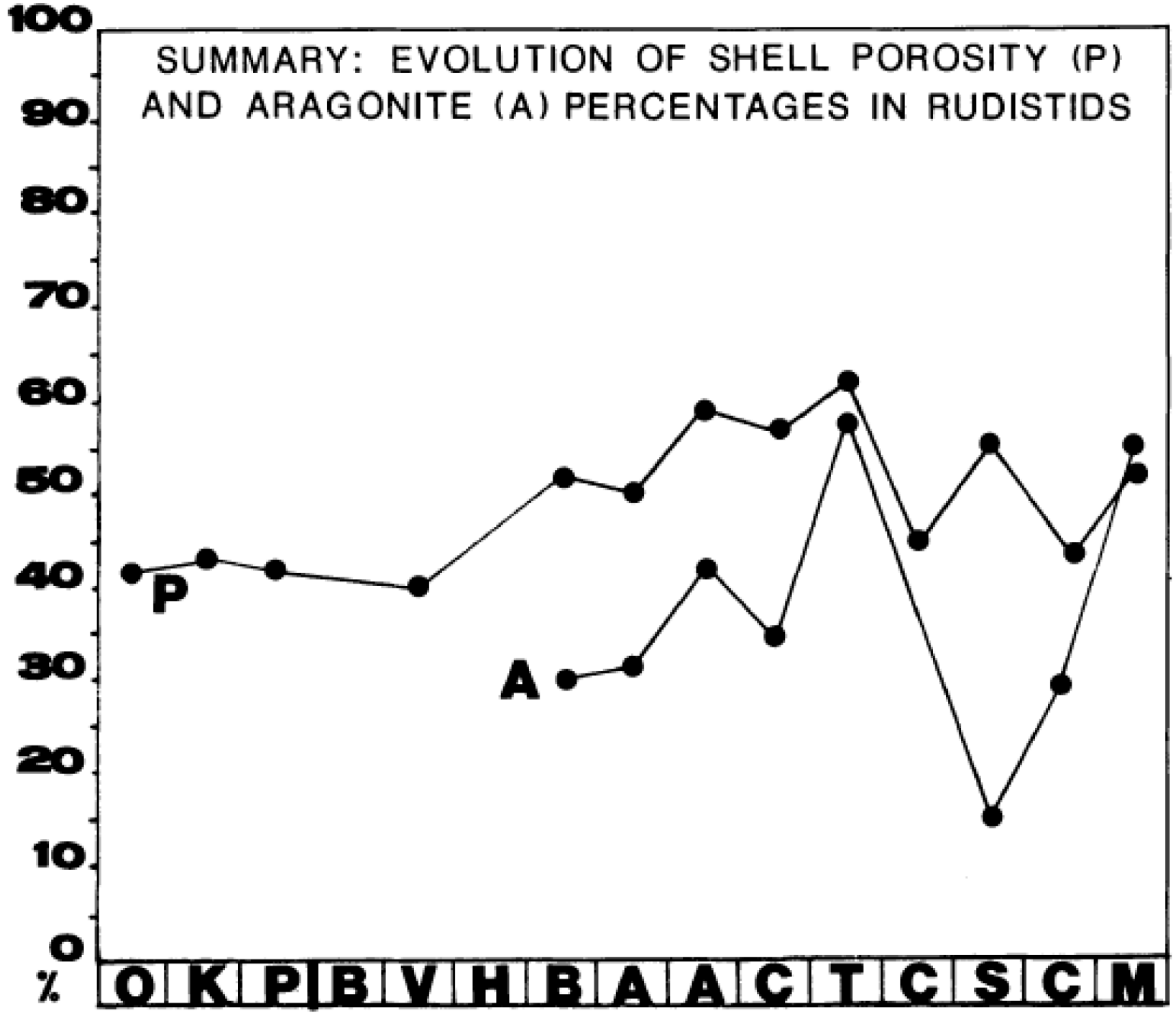


Figure 4. Summary of analyses of percent aragonite (A) and percent pore space (P) (see Figure 8 for method) averaged for 278 Upper Jurassic-Cretaceous rudistid species, representing all families (from Johnson, 1984). Stages coded by letters at base. Note co-evolution and increasing relative importance of stronger aragonitic shell layers and shell porosity (mainly as wall pores, accessory cavities) during the Barremian-Turonian, coincident with migration onto, and even- tually dominance of, prime shallow-water reef ecospace by rudistids. Turonian-Santonian decline in both parameters probably reflects more organized arrangement and diminishing size of wall pores characteristic of more advanced rudistids, and the dominance of mainly calcitic Radiolitidae in reef-building. This was followed by a rise in values reflecting Santonian to Maastrichtian dominance of largely aragonitic Hippuritidae (From Kauffman E. G., 1988).