CONODONT COLOR ALTERATION, AN ORGANO-MINERAL METAMORPHIC INDEX, AND ITS APPLICATION TO APPALACHIAN BASIN GEOLOGY

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ABSTRACT

Conodonts are apatitic marine microfossils of Cambrian through Triassic age. During incipient metamorphism (50°–300°C) they change color from pale yellow to brown to black due to carbon-fixing within the trace amount of organic matter in their skeletons. As thermal metamorphism continues (300°–550°C), conodonts change from black to gray to white to crystal clear as a result of carbon loss, release of water of crystallization, and recrystallization. The conodont color alteration technique provides a unique link between mineral and organic indexing of thermal metamorphism and is best suited for carbonate rocks.

Conodont color alteration index (CAI) isograd maps for three stratigraphic intervals in the Appalachian basin show: (1) Conodont color alteration is directly related to the depth and duration of burial and the geothermal gradient. (2) Tectonics affect color alteration only where folding and faulting act to significantly increase depth of burial. (3) Isograds and overburden isopachs are conformable throughout most of the northern half and in the western part of the southern Appalachian basin; in these areas, isograd values gradually increase eastward except for a major disruption in the area of the Rome trough. (4) South of central Virginia, isograds are disrupted and irregular because late Paleozoic thrusting has severed and telescoped original burial metamorphism isograd patterns. (5) Basin restoration using conodont CAI isograds indicates a maximum shortening in northeast Tennessee of about 115 miles (185 km). (6) The CAI 2 isograd (=brown conodonts) for each stratigraphic interval lies near the eastern limit of oil production for that interval; this limit shifts eastward for each successively younger stratigraphic interval concomitant with decreasing overburden. (7) Gas production is less related to isograds and depends mostly on primary and (or) secondary porosity and permeability. The CAI 4 isograd (=brownish-black conodonts), however, approximates the eastern limit of gas production because the temperature (depth of burial) necessary to produce this high level of organic metamorphism concurrently produces mineral metamorphism that reduces porosity and permeability and the likelihood of commercial reservoirs.

INTRODUCTION

The thermal level of diagenesis or metamorphism of a rock can be evaluated from its mineral and (or) organic constituents. Incipient to high-grade metamorphic mineral assemblages (50° to +800°C) have been determined for pelitic sedimentary and volcanogenic rocks (Hower, 1976 and this volume; Turner and Verhoogen, 1960). Identification techniques for determining incipient to high-grade metamorphic mineral facies range from X-ray diffraction analysis of clay minerals to megascopic field identification of porphyroblasts, respectively. The equivalents of incipient to low-grade mineral metamorphic indices (300°–300°C) have been determined for organic materials such as kerogen, vitrinite, and palynomorphs (see Bostick and Damberger, 1971, Table 1). Indexing of organic materials is accomplished by means of chemical analysis, spectral fluorescence, reflectance or transluscence photometry, or visual color comparison. Organic indices are generally used for assessing temperatures of <300°C, whereas mineral indices are used for higher temperatures. It is noteworthy that the mineralogy and the depositional and post-depositional environments of pelitic rocks have made them the chief source of most organic and mineral metamorphic indices. For the same reasons, carbonate rocks have been, until now, unsuitable for assessing thermal metamorphism.

A unique link between mineral and organic indexing of thermal metamorphism is provided by the conodont color alteration technique which combines both mineral and organic indexing in one element. This technique is applicable in the temperature range of 50° to 550°C and is best suited for carbonate rocks.

Although most of the earlier work concerning conodont color alteration indexing (Epstein, 1976; Epstein and others, 1977) dealt with the experimental laboratory data that justify the technique, this report deals chiefly with its application, as the experimental data are now published.

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CONODONTS

Conodonts (Fig. 1) are apatitic marine microfossils (generally 0.1–1 mm) that contain trace amounts of organic matter. They are the hard parts of an unknown organic group of worldwide distribution in Cambrian through Triassic rocks and are valuable index fossils for biostratigraphic