II. PRECAMBRIAN PETROLEUM

PRECAMBRIAN AS A HYDROCARBON EXPLORATION TARGET

Albert B. Dickas

ABSTRACT

As recently as 1950 it was generally accepted that sedimentary rock of Precambrian age located within basins, geosynclines, and platforms could not contain hydrocarbon deposits. The absence of pre-Paleozoic Era life and the lack of reservoir rock characterisitics in these Precambrian rock columns were the most often presented reasons why Precambrian terranes should be ignored by the petroleum geologist. Within the past three decades evidence for varied forms of life has been discovered in sedimentary rock as old as 3.6 Ga. Simultaneously many Precambrian rock columns have been recognized as possessing excellent reservoir characteristics. With the discovery of commercial deposits of indigenous Precambrian-age hydrocarbons, sedimentary rock deposited throughout the world during this early chapter in earth history is being analyzed by the oil and gas industry.

INTRODUCTION

The seven basic requirements necessary for the formation of any hydrocarbon deposit are deposition of organic source material, maturation of source rock, migration of developed hydrocarbons, accumulation under reservoir characteristics, concentration by trapping mechanisms, containment by sealing conditions, and preservation of hydrocarbons through geologic time.

Of these, the three most often denied serious consideration within the time-frame of the Precambrian are those of presence of source and reservoir strata and potential for preservation of hydrocarbon.

PRECAMBRIAN SOURCE ROCK POTENTIAL

To many, Precambrian rock is seen as the end geologic product of thousands of millennia, during which molten and turbulent events created earth environments entirely unfavorable to the development of petroleum and natural gas. The exploration philosophy of many active petroleum geologists is directed by the belief that extensive, prolonged tectonism, characterisitic of the Cryptozoic, did not allow the evolution or preservation of life forms. Jones (1956) emphasized this bias and stated that "the recognition of evidence of life in Pre-Cambrian strata is one of the most controversial problems in all geology, and there is considerable doubt expressed by many paleontologists concerning the nature of the microfossils which have been reported." Meinschein (1965) agreed that "until 10 years ago [that is, 1955] it was widely believed that life on earth originated near the beginning of the Cambrian time."

These statements expressed 30 and 20 years ago aided in the development of undergraduate and graduate school philosophies of many petroleum geologists presently operating at the district, division, and board level. That these philosophies still undergird exploration philosophies in many American organizations is documented by the timidity with which American geologists, even today, approach the Precambrian as a hydrocarbon frontier. This timidity is startling when compared to successful Precambrian exploration programs undertaken by geologists in the Soviet Union, China, and Australia since the early 1960s.

By 1965 less than 300 papers dealing with the subject of Precambrian life had been published (Murray and others, 1980). This record has increased more than fivefold and includes discoveries of fossil life from both shield and non-shield areas of all the principal landmasses. The following short list of significant occurrences, arranged in order of decreasing geologic age, is illustrative of the richness and extent of the Precambrian fossil record.

Warrawoona Group of Western Australia: single-celled spheres, filaments and stromatolites, approximately 3.5 Ga (Dunlop and others, 1978).
Onverwacht Series of South Africa: spheroidal and hemispheric-shaped algae-like bodies, minimally dated at 3.2 Ga (Engel and others, 1968), possibly the oldest known structurally preserved fossil organisms (McKirdy, 1974), occurring in the oldest "little-altered sedimentary rocks on earth" (Levin, 1983).

Fig Tree Group of South Africa: rod-shaped, bacteria-like, blue-green algae spheroidal bodies, approximately 3.1 Ga (Barghoorn and Schopf, 1966).

Bulawayan Group of southern Rhodesia: occurrence of stromatolites (McKirdy, 1974) dated from 2.7 to 3.0 Ga; carbon 12/13 ratio is suggestive of biologically produced atmospheric oxygen and fixation of carbon dioxide by photosynthesis (Levin, 1983).

Gunflint Iron Formation of the Lake Superior region: a varied and spectacular assemblage of thread bacteria and blue-green algae, 1.9 Ga (Tyler and Barghoorn, 1954), discovery of these fossils "represented the first definitive evidence of life before the age of visible animal life" (Cooper and others, 1986).

Bitter Springs Formation of Australia: possibly oldest known evidence of eukaryotic (nucleated) celled fossils, 900 Ma, beginnings of life with genetic variability and sexual reproduction capacities (Schopf, 1968).

Pound Quartzite, Ediacara Hills of southern Australia: appearance of metazoan (multicellular) jellyfish, corals, flatworms, echinoderms, and arthropod-like animals, 570 to 650 Ma (Glaessner, 1961).

The Precambrian era was the time when life originated on earth. Yet the recognition that fossil- and organic-rich sedimentary rock form a significant part of the Precambrian record is a recent development (McKirdy, 1974). The above examples and other Precambrian beds rich in organic material do not differ in any respect from much younger Phanerozoic beds in their potential as hydrocarbon source units. Studies have shown that certain Precambrian sections are distinguished by containing as much organic carbon as considerably younger rock of equivalent lithofacies (Nanz, 1953; Shaw and others, 1967). This is especially true of Proterozoic sedimentary rock, in which a sixfold enrichment of organic carbon is found compared to older strata (McKirdy, 1974). The suggestion that even these late Precambrian beds might not contain quantities of organic matter sufficient for the formation of hydrocarbon is negated by oil seeping from the 1.04 Ga Nonesuch Formation in the Lake Superior region and the significant reserves of indigenous Proterozoic oil and gas discovered since 1962 in the Siberian Platform (Vassoyevich and others, 1971).

PRECAMBRIAN RESERVOIR ROCK POTENTIAL

J.J. Sederholm is reported to have been one of the first geologists to realize that "there was no obvious reason why Hutton's principle [of uniformitarianism] should be limited to the Cambrian and later period" (Holmes, 1965). Thus was adopted the hypothesis that the tectonic development of the earth's crust has been a continuum since early Precambrian time. Over the past several decades it has been noted and emphasized that Precambrian erosional and depositional processes created sedimentary columns lithologically similar to those of younger sedimentary rock sequences. McKirdy (1974) placed the continuum of sedimentary processes in perspective by observing that the "overall continuity of similar sedimentary facies and their lithologic expressions into the Phanerozoic provides little evidence of sudden sedimentological or geochemical change accompanying, or immediately preceding, the onset of Cambrian sedimentation."

Today, Precambrian columns the world over are recognized as containing sedimentary rock unaffected by severe regional metamorphism and possessing porosity, permeability, sedimentary, and thermal history characteristics favorable to the accumulation of hydrocarbon. These columns include the Riphean and Venian of Russia, the Sinian of China, the Vindhyan of the Hindustan Platform, the Lalun and Hormuz of Iran, the Bundu and Volta of Africa, and Belt and Keweenawan of North America. In Australia alone more than 20 basins, geosynclines, or platform areas are recognized as containing normal Proterozoic sedimentary columns (Compton and Arriens, 1968). Becker and Patton (1968) summarize the potential for reservoir characteristics within Precambrian rock by stating that "evidence does not support the view that a particular system of sedimentary rocks is the lower limit of petroleum entrapment solely because of its great age."

PRESERVATION OF PRECAMBRIAN HYDROCARBON

The third consideration regarding the supposed improbability of Precambrian hydrocarbon reservoirs requires little discussion here. Debate suggesting a lack of Precambrian oil or gas reserves is generally supported by several courses of reasoning.

The decline of known hydrocarbon reserves as a function of increasing geologic time would suggest absolute minimal to zero volumes indigenous to Precambrian sedimentary rock columns; the lapse of approximately 600 m.y. since the termination of the Precambrian Eon, accompanied by continuing burial and diagenesis would suggest that any Precambrian hydrocarbon accumulation discovered today would have been reduced to the tar residue stage; and even if hydrocarbon accumulations had been formed during the Precambrian, such would in all probability have been subsequently lost due to destruction of the trapping mechanism by erosion or faulting.

The presence of economic deposits of indigenous Precambrian oil and gas in the Soviet Union and China negate these positions.

CONCLUSIONS

Precambrian sedimentary rock terranes should not remain outside the exploratory domain of the petroleum geologist. All factors necessary for the formation of economic hydrocarbon deposits have been in operation throughout the past 3.5 b.y. The initiation of sedimentary rock processes some 3.7 Ga and the advent of life some 3.5 Ga brought into co-existence the factors necessary for the creation of oil and gas fields.

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