

parameters in combination. These results are achieved by using a new quantitative approach based on concentrations and ratios of specific biomarkers by integration of mass chromatograms. The assessment of all parameters in combination results in a well-documented, internally consistent picture permitting the above conclusions. In addition, these biomarker data permit in hindsight a reasonable interpretation of the wide range of carbon isotope data. All results are consistent with the geologic setting. The approach adds a new dimension in assisting the petroleum explorationist toward paleoreconstruction.

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South-Aniuy Suture (West Chukotka)

The geologic data indicate that Phanerozoic and probable late Proterozoic rocks of Chukotka and Alaska are very similar. The paleomagnetic results indicate that during most of the Phanerozoic, the drift of the North American craton did not conform to the drift of the Siberian craton. This contradiction can be settled only by searching for a suture within the bounds of northeastern Siberia, along which the North American plate once apparently collided with the Siberian plate. To the west of the Okhotsk-Chukotka belt there is only one suture possessing all the features of an ophiolitic suture—the South-Aniuy. Its characteristic features are linearity, large extent, and abundant ophiolites and turbidites. It is probably the site of the collision of the Hyperborean and North Asiatic plates. During the Late Jurassic these plates collided with the accompanying subduction of the oceanic lithosphere southwestward and the formation on the northern margin of the Omolon massif of a zone of island arcs and back-arc basins with characteristic sedimentation and magmatism. On the whole the geologic data on the structure, metallogeny, and history of development of West Chukotka agree with the hypothesis of a marginal-continental location of wide regions of the northern part of the Omolon massif over a former subduction zone. The Late Jurassic (Volgian) volcanism fixes the most active deformation along this zone and the bringing together of the plates. More clear becomes also the position of the Triassic volcanism of the Oloy-Aniuy interfluvium which probably reflects another, but more transitory appearance of a subduction zone on the margin of the continent.

After collision (possibly with some transcurrent movements) of the Hyperborean and Asiatic plates, the geodynamic conditions in the northeastern part of Asia changed and the whole territory to the west and the north of the Okhotsk-Chukotka belt was already a united continental monolith with an old "cicatrice"—the South-Aniuy suture zone.

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Changing Patterns of Phosphogenesis in Mesozoic and Cenozoic

During the Mesozoic and Cenozoic Eras, major global phosphogenic episodes occurred during the Upper Cretaceous-Eocene and Miocene Epochs. A minor phosphogenic episode occurred during the Jurassic Period.

The Jurassic and Miocene phosphogenic provinces were

primarily located on the eastern sides of oceans on continental shelves where upwelling ocean paleocurrents were associated with paleotrade winds. Major exceptions are the Miocene phosphorites of the southeastern United States which probably were associated with the paleo-Gulf Stream, and the Miocene phosphorites of the Chatham Rise, New Zealand, which possibly were associated with the Antarctic circumpolar paleocurrent. The Miocene phosphorites probably were the result of increased vertical oceanic circulation, mainly trade-wind belt coastal upwelling. Jurassic phosphorites appear to be paleo-oceanographically analogous to the Miocene phosphorites.

The Late Cretaceous-Eocene phosphogenic province was primarily an east-west equatorial circumglobal province of Tethys and Pacific seamounts. The Upper Cretaceous-Eocene phosphorites of the Atlantic paleo-ocean continental shelves in Togo, Gabon, Senegal, and Brazil are an exception to this distribution. The major Upper Cretaceous-Eocene phosphorites probably were the result of vertical circulation due to equatorial divergent upwelling.

Tertiary and Mesozoic phosphogenic episodes appear to be due to a combination of the onset of increased rates of oceanic circulation after periods of oceanic stability, periods of high sea level, and favorable paleogeography.

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Economics of Small-Scale Oil Shale Retorts

A graphic portrayal of conventional oil in the United States and Saudi Arabia since 1880, vis-a-vis a series of predictions since 1918 of the economic feasibility of obtaining oil from shales, has been used to examine the problems and prospects for commercialization of oil shale in the United States. Time series analysis, and analogy to R. M. Catlin's 1920 commercial plant and Union Oil's 1957-58 aborted commercial entry reveal that the economic infeasibility of shale oil is not merely the result of inflation; subjected solely to the influences of inflation, oil from shale would today cost only slightly more than \$8.00 per barrel.

Given this rejection of inflation as the prime deterrent to commercialization, the most critical factors which continue to cause cost projections for shale oil to exceed even OPEC's escalation of oil prices since 1973 are identified. The work of Edward W. Merrow and the RAND Corp., have identified some of these constraints. A review of state-of-the-art extraction and environmental technology, and the more common theories as to the continued economic infeasibility of commercial scale plants lead to a focus on seven specific factors—two economic and one each of technologic, financial, logistic, environmental, and socio-economic/political.

A potential resolution or significant mitigating influence has been identified for each of these factors, the proposal's synergism examined and commercial operation under it compared to more conventional alternatives. A conceptual feasibility study and computer sensitivity analysis reveals the potential for oil shale prices well below those of conventional oil. Based on current oil industry statistics, a forecast of the long-run market potential of shale oil and a surprising estimate of eventual market segmentation have been made.

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Highlights in History of Geophysical Exploration

While some preliminary geophysical studies were made in