Elemental Geochemistry of Source-rocks from the Buxin Formation (Lower Eocene) in the Sanshui Basin, South China

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The Sanshui Basin, located in the middle part of Guangdong Province, South China, is an oil-bearing fault depression with lacustrine sediments of Cretaceous to Paleogene age. The Honggang Member of the Buxin Formation (Lower Eocene) is the main oil source bed of the basin. This work aims at assessing the sedimentary environments of the source rocks based on elemental geochemical data. The distribution of elements (Al, Ti, Fe, Mg, Ca, K, Na, P, Mo, U, V, Ni, Co, Cr, Cu, Zn, Sr, Ba, Cd, Li, Mn and Pb) and elemental ratios serve as proxies for palaeoenvironmental conditions. The Honggang Member can be subdivided into 3 submembers. Elemental concentrations and ratios in Submember A indicate higher terrigenous fluxes with relatively constant chemical composition and low-O_2 bottom waters with higher salinity than the other submembers. Highly saline bottom waters were probably the consequence of intermittent sea water incursions. Submembers B and C, mainly composed of alternating laminated, organic-rich and microbioturbated, organic-lean shales, are characterized by large variations in geochemical features, which reflect rapid fluctuations in palaeoclimate and sedimentary conditions. The laminated shales, deposited during humid intervals, show higher values of elements that are usually enriched in terrestrial detrital minerals and lower concentrations of endogenic elements. Palaeoredox indices suggest anoxic bottom water conditions resulted from a mixture of salinity stratification and thermal stratification, which were favourable for organic matter preservation. The intervals of dry climate, represented by organic-lean shales, show lower concentrations of terrigenous elements and higher values in endogenic elements with reduced terrestrial input and increased evaporation. Palaeoredox proxies indicate prevailing oxygenated to dysoxic environments developed in bottom waters. Salinity indices for the uppermost part of the Honggang Member show lower values, suggesting that an increasing input of fresh waters caused freshening of the lake waters.

Characteristics of Lithologic Petroleum Reservoirs

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On the basis of the geological conditions and formation processes for lithologic reservoirs and their distribution characteristics, we conclude that the development of lithologic reservoirs requires unique geological conditions. They include six aspects: (1) lithologic traps formed at an early stage and developed over a prolonged period; (2) lithologic reservoirs associated with primary migration and short distance secondary migration pathways; (3) lithologic reservoirs charged by hydrocarbons in an early stage; (4) lithologic reservoirs experienced little or no structural destruction after the initial charge; (5) lithologic reservoirs distributed in both low potential and high potential areas; (6) lithologic reservoirs associated with both low stand system tracts (LST), and high system tracts (HST). The results of recent oil and gas exploration in China show that the lithologic reservoirs are excellent for hydrocarbon accumulation and may have great exploration potential. This type of reservoir should become a major play type in future exploration.

Formation Mechanisms and Distribution Patterns of a Deep Volcanic Gas Reservoir in Songliao Basin, East China

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A giant gas reservoir has been found while exploring the deep layer of a faulted depression in the Songliao Basin, northeast China. The gas was sourced from the early Cretaceous lacustrine mudstone-bearing coal (the Shahezi Formation). The source rocks, about 200-500 m thick, consist mainly of kerogen type II or III rocks and have a high thermal evolution degree. The reservoir rocks are of the early Cretaceous volcanics with predominant acidic rhyolite (the Yingcheng Formation) with an estimated reservoir interval of 100-400 m thick. The volcanics are distributed along a deep fault belt with abrupt facies variations laterally indicating several volcanic eruptions. The cap rocks in the area are a 100-300 m thick mudstone (Denglouku-Quantou Formation). The gas reservoir is of a structural-stratigraphic reservoir play with the extent of the gas accumulation being controlled primarily by the volcanic features. The giant gas accumulation is controlled by the hydrocarbon kitchen and facilitated by the presence of some favorable local structures and. Most of the gas has been found to be associated with the areas around the uplift and the slope belts near the deep fault.

The Discovery of an Oolitic Reservoir Play Type in the East Sichuan Basin and Its Implications

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The discovery of an oolitic beach reservoir play type in the lower Triassic Feixianguan Formation in the east Sichuan Basin marks a significant breakthrough in the natural gas exploration in the basin. Thirteen oolitic beach reservoirs have been discovered with an estimated geological gas reserve of approximately 229.22×10^9 m^3. Through dolomization by an early mixed water and transformation during a late burial dissolution, the oolitic beaches, which were deposited on carbonate platforms, developed into a residual oolitic dolostone forming the main reservoir rock. The oolitic reservoir rocks are of good reservoir quality. Their distribution

was apparently controlled by the sedimentary facies. The best reservoir zones lie at the edge of carbonate platform. The oolitic reservoirs are visualized as high-amplitude “bright spots” in conventional seismic time sections. Their distribution can thus be predicted quantitatively by special processing of the seismic data. This study shows that accurate understanding of the oolitic depositional model and the use of quantitative seismic prediction technology are critical in the discovery of the oolitic reservoir plays.

Diapiric Pathway System and Its Constraints on Migration and Accumulation of Natural Gases in the Yinggehai Basin, South China Sea

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Regional diapir activities, deep overpressure systems and high geothermal gradients in the Yinggehai Basin, South China Sea had important influences on the generation, migration and accumulation of the natural gases in the basin. The Miocene source rocks rich in terrestrial organic matters in the basin are within an over-pressured zone.

Geophysical and geochemical data indicate that the diapiric faults and fractures that cut through the Miocene sediments provide major pathways for upward gas migration with abnormal pressure with sand bodies connected with the faults and fractures acting as relaying conduits. Overpressure is the main driving force for vertical and lateral migration of the gases. Episodic discharge of the deep over-pressured fluids caused the faults and fractures to react periodically, resulting in multiple filling episodes in the reservoirs. The confined episodic gas migration has significantly increased the hydrocarbon expulsion efficiencies and provided favorable conditions for large-scale gas accumulation within the diapric structures in a short time. The compositional heterogeneities and carbon stable isotope data of the gases indicate three phases of gas migration: initially biogenic gas, followed by thermogenic hydrocarbon gas, and then CO2-rich gas. The filling processes occurred within approximately 1.5 to 0.1 Ma based on the kinetics modeling. As the gas migration and distribution were controlled by faults associated with diapiric activities, the transitional pressure zones around the shale diapir structures are on the gas migration pathways and may therefore be favorable zones for gas accumulation in addition to the shallow diapir structures in the Yinggehai Basin.

New Exploration Plays in the Bohai Bay Basin, East China

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The Bohai Bay Basin, east China, is a mature oil exploration basin offshore. The major hydrocarbon producing intervals include the Palaeogene plays (e.g. Shengli and Liaohe oilfields), pre-Cenozoic plays (e.g. Huabei Oilfield), and the Neogene uplift plays (around Bozhong Oilfield). The Neogene sag plays were recently identified as new exploration targets in the mature basins. Two new models for oil pool accumulation in the basin have recently been established including (1) ”Transfer Station” hydrocarbon migration model, and (2) four varieties of ”Faulted Sand” assemblage model. The ”Transfer Station” model evaluates whether hydrocarbons can be migrated from the deeper Palaeogene to the shallow Neogene plays through transfer zones. The ”Faulted Sand” assemblage models predict the most favourable hydrocarbon enrichment blocks. The new models have been applied in the Bohai Bay region and have led to an important breakthrough in finding new petroleum resources in the existing mature basin.

Geology of Subtle Gas Pools in the Yinggehai and Qiongdongnan Basins, South China Sea

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The Yinggehai and Qiongdongnan (Y-Q) basins, located in the northern part of the South China Sea, are two major Cenozoic hydrocarbon-bearing sedimentary basins. Large gas accumulations have been discovered recently in a variety of subtle traps including sandstone wedges, incised valley sandstones, delta front and pre-delta turbidite sands associated with diapir structures.

The widespread development of a variety of subtle traps in the Y-Q basins is attributed to the unique geological setting in the basins. The tectonic setting and evolution of the Y-Q basins is similar to the Atlantic passive marginal basins and is conducive for the development stratigraphic traps. Some of the second and third order sequence boundaries were associated with major regional tectonic events and provided the necessary tectonic- stratigraphic framework for the development of subtle traps. During the course the basin evolution a wide variety of depositional regimes from fluvial, through shallow marine to deep marine and associated depositional processes were present, which provided the essential sedimentary facies elements for the subtle trap development. The presence of diapir structures within the Y-Q basins also provided favourable conditions for the formation of subtle traps. Major subtle trap types discovered in the Y-Q basins can be grouped according to the tectonic evolution phases of the basins including (1) syn-rift fault block and lithologic composite traps, unconformity-stratigraphic traps, fault nose; (2) post-rift stratigraphic and lithologic traps, pre-delta and delta front turbidites; (3) passive margin shelf sandstone lithologic traps, incised valley and basin floor fan sandstone lithologic traps.

Petroleum Geology of the Songpan-Aba Area: One of the Last Frontier Basins in China

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The Songpan-Aba area is similar to the sedimentary basins on the Yangtze Block. Following the initial rifting and separation of the Yangtze block in the Early Palaeozoic, the Songpan-Aba area was gradually developed into a passive margin basin. As the Qinling-Qiliang oceanic crust subducting and closing, the Caledonides was formed and the basin superimposed upon the existing foreland basin. Being influenced by the Palaeo-Tethys

extension, the late Palaeozoic gave birth to intro-continental rifting margin basins. Following the formation of the peripheral orogenic belts, the late Triassic again superimposed on the existing foreland basin. The Mesozoic and Cenozoic superimposed the faulted basins as the Qingzang Plateau domed. Hydrocarbon source rocks of the Lower Palaeozoic passive margin basin and the Upper Palaeozoic platform facies carbonate and the Triassic mudstone sediment form the main source-reservoir-seal combination in the Songpan- Aba area. The sediments of this area are in an advanced stage of diagenesis, having entered into the middle and high diagenetic stages. Except for the highly mature Triassic and Permian in the Ruoergai and Hongyuan areas, almost all the areas are in the early stage of over mature, generating much methane. The Songpan-Aba area has an enormous potential for gas discoveries.

Paleozoic Reefs and their Development in the Sichuan Basin, China

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The Sichuan Basin, with about 19×10 km^2 in area, is not only a very important tectonic and sedimentary basin, but also the oil bearing basin on the Upper Yangtze Platform. With the stable tectonic development from Early Paleozoic to Middle Triassic, the reefs were very well developed in Early Cambrian, Early Silurian, Devonian and Late Permian. Geographically, the Cambrian reefs distributed on the north and northeastern margin of the basin. The reefs include cyan bacteria—Archaeocyathus reefs, thrombolite micrite mounds, oncolite biostromes and bioclasic & oolitic banks. The reef-building organisms include archaeocyathus and cyanobacteria; the living organisms include brachiopods, trilobites, crinoids and sponges. Comprising patch reefs, mudmounds and biostromes, the Silurian reefs occurred on the north and south margin of the basin in the Llandoverian to Wenlockian, when the area was storm influenced siliciclastic and carbonate ramp environment. The Permian reefs were observed in the Changxing Fm in eastern and northeastern Sichuan, and can be divided into three types: platform margin reefs, mud mound in the low platform slope, and patch reefs within the platform. The reef-building organisms mostly include Sphinctozoa, Inozoa, Hydrozoa, and Tabulozoa; main binding organisms are blue green algae, Tubiphytes and Tabulozoa. The reef-living organisms mainly include bryozoa, brachiopoda, foraminifera and echinodermata. The formation and distribution of the Permian reefs are vulnerable to regional topography controlled by major faults. In general, development and distribution of the Paleozoic reefs in Sichuan Basin were controlled by regional sea level changes and various tectonic movements.

Sequence Stratigraphy and Lithofacies Paleogeography of the Tremadocian (the Latest Cambrian to Early Ordovician) in the Hunan and Hubei Region, China

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Four third-order sequences have been recognized in the latest Cambrian to Early Ordovician Tremadocian successions in the Hunan and Hubei part of the Yangtze platform. These four sequences could be well correlated with each other in different depositional settings of the Yangtze platform, indicating four third-order transgression - regression cycles. The integration of sequence stratigraphy and facies analysis has improved our understanding of the evolution of lithofacies and palaeogeography in the region. This can help predict locations of better-quality carbonate reservoirs such as the lowstands karst-developed limestone reservoirs. At the beginning of the early Tremadocian, the depositional facies from northwestern Hubei to central Hunan change successively from tidal flat, tidal lagoon dolomite facies through restricted carbonate platform, open carbonate platform, platform margin shoal complex, to platform marginal slope and the black carbonaceous shale basin. During the early stage of the Tremadocian, relative sea level fall caused gradual regression from north to south, resulting in depositional environments varying from tidal flat, tidal lagoon dolomite facies, restricted carbonate platform, to platform margin shoal and outer shelf. During the middle Tremadocian, a new transgression resulted in onlapping of the bioclastic limestone and shale towards the Qingfeng-Xiangguang fault zone to the north. During the late Tremadocian, another relative sea level fall caused a further slow regression, and the open carbonate platform in Hubei and northwestern Hunan was developed with the bioclastic shoal of inner shelf and platform margin shoal complex.