Petroleum System of Early Cretaceous Forearc Basin: Sinop Basin, Central Black Sea Onshore - Northern Turkey*

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Abstract

The Sinop Basin is an Early Cretaceous forearc basin that was initiated by extension during the Early Cretaceous in Central Pontides (north Turkey). Rifting began in the middle Barremian and Aptian to Albian syn-rift clastic dominated sediments including the shallow marine and turbiditic sandstones. Syn-rift stratigraphic units in the Central Black Sea onshore basins of Aptian to Albian age are exposed along the southern sector of the Sinop Basin. Aptian to Albian aged black shales have good hydrocarbon source rock potential based on the geochemical properties. Rock-Eval pyrolysis analyses results of Early Cretaceous shale-rich intervals indicate that good to excellent oil-gas prone source rocks are present in paper and laminated shales. Source rocks facies of Early Cretaceous black shales was deposited within depression areas with anoxic environmental conditions. Total organic carbon (TOC) ranges from 0.8 to 2.5% and hydrogen index (HI) values reach up to 350 mg HC/g TOC is present in low maturity shale samples in the Sinop Basin. The Ekinveren oil seep is being observed in the southern part of the Sinop Basin. Carbon isotope analysis, biomarker ratio and oil-source correlation studies indicate that the Ekinveren oil seep is correlatable with Lower Cretaceous black shales in the basin. Albian aged sediments are well known in the Romanian offshore and have been one of the main reservoir targets for hydrocarbon exploration. Albian sandstones are composed of thick sand-rich proximal turbidite successions interbedded with siltstones and mudstones in the Sinop Basin. Channelized stratified sandstones and non-channelized massive sandstone layers of proximal channel turbidite and sheet-sands have poor to good quality reservoir properties. Sand to shale ratio is increasing within the lower part and decreasing to the upper part of the Early Cretaceous succession in the Sinop Basin. Potential reservoirs within the lower part of Early Cretaceous sedimentary package are represented by 20-30 m thick quartzite arenite facies overlying the Late Jurassic shallow marine to platform carbonate units. The reservoir quality of the Early Cretaceous sand-rich facies is mainly controlled by depositional facies and diagenetic alteration in the Sinop Basin. The mineral composition of the turbiditic sandstones also has a major effect on porosity and permeability.

Introduction

The Sinop-Boyabat area, which is located northern part of Turkey, is one of the important prospective area for hydrocarbon exploration in the Pontid belt, with the presence of source, reservoir and seal rocks (Figure 1). Ekinveren oil seeps within the southern marginal part of the basin indicate that active hydrocarbon systems in Sinop-Boyabat area. The first rifting phase occurred in Early Jurassic (Liassic) and thick clastic dominated sequences were deposited in the B Sinop basin. The first rifting phase ended in the Dogger and is succeeded by carbonate platform formation from the Late Malm to Lower Cretaceous in Central Pontid area (Yilmaz, 2002).

Stratigraphy and Structure

The Sinop basin started its development as a rift associated with the volcanic arc in Lower Cretaceous time by the northward subduction of the Neotethys oceanic plate beneath the southern margin of Eurasia (Yilmaz and Tuysuz, 1988; Tuysuz, 1990; Tuysuz, 1999) and turned into an asymmetrical Fore-arc Basin in Campanian–Maastrichtian time as the rifted volcanic arc (Aydin et al., 1995; Tuysuz, 1999; Leren, 2003). Mesozoic sedimentation begins with the Early Jurassic (Liassic) Akgol Formation. The Akgol Formation consists of clastic dominated siliciclastic deposits, which rests unconformably on pre-Jurassic aged metamorphic basement rocks. The Akgol Formation is overlain by the fluvial sediments of Burnuk Formation with a low angle unconformity surface in middle Jurassic. The Burnuk Formation is overlain by Late Jurassic aged different carbonate lithofacies of Inalti Formation, which were deposited in a high-energy shelf and platform depositional environment. Late Jurassic platform and shelf carbonates in the Sinop Basin are unconformably overlain by Aptian to Albian syn-rift sediments including shallow marine sandstones, submarine olistostromes and turbidites.

The post-rift sediments consist of pelagic mudstones, shales, carbonates and marls of Late Cenomanian and younger ages. The thickness of Late Cretaceous sedimentary succession reaches up to 2000 m within the basin. This sedimentary succession begins with the Turonian-Coniacian-Santonian aged Kapanbogazi Formation, which is composed of red pelagic limestone resting unconformably on the older rock stratigraphy units, and is overlain by turbiditic sandstone – shale intercalations with volcanogenic rocks of the Late Cretaceous aged Yemislicay Formation. Kapanbogazi Formation is interpreted to mark the change from rift to drift in the Western Black Sea (Görür et al., 1983). The succession grades upward into the Campanian– Maastrichtian aged Gursoku Formation (Aydın et al., 1986; Tuysuz et al., 2004).

This unit consists of thick distal turbiditic deposits in the basin. Early Campanian – Paleocene aged Akveren Formation is composed of proximal to distal turbidites and carbonates, grades into Paleocene-Eocene aged siliciclastic deposits that are unconformably covered by younger rocks (Figure 2). Sinop basin is an Early Cretaceous Fore-arc Basin that was initiated by extension during the Early Cretaceous in Central Pontides (northern Turkey). Second rifting began in the middle Barremian and Aptian to Albian syn-rift clastic dominated sediments including the shallow marine and turbiditic sandstones. Syn-rift rock stratigraphy units in the Central Black Sea onshore basins of Aptian to Albian age are well exposed along the southern sector of the Sinop Basin (Figure 3). The Early Cretaceous sedimentary succession of the Sinop-Boyabat area starts with the quartz rich siliciclastic turbiditic sandstone, siltstone, mudstone alternations and paper, black shales of the Caglayan Formation over the Late Jurassic platform to shallow marine carbonates of the Inalti Formation with an unconformity surface. This unit is also characterized by carbonate mass-flow deposits with conglomerates and olistoliths of various sizes.

The Lower Cretaceous Caglayan Formation is dominated by a succession of paper and black shale above gray to brownish quartz siltstone. The thickness of shale-rich successions reaches up to 400 m especially in the central part of the basin. The thickness of the Lower Cretaceous deposits is between 400 and 2,000 m in the Sinop-Boyabat area and it might be thicker in the central and thinner in the marginal part of the basin but its presence has been complicated by Cretaceous normal faulting and Eocene thrusting, folding and strike-slip events in the region.

Hydrocarbon Potential

Aptian to Albian aged black shales have good hydrocarbon source rock potential based on the geochemical properties. Rock-Eval pyrolysis analysis results of Early Cretaceous shale-rich intervals indicate that good to excellent oil-gas prone source rocks are present in paper and laminated shales. Source rocks facies of Early Cretaceous black shales was deposited within depression areas with anoxic environmental conditions. Total organic carbon (TOC) contents are between 0.8 to 2.5% and hydrogen index (HI) values of up to 350 mg HC/g TOC are present in low maturity shale samples in Sinop Basin. The types of the kerogen are II and III (mainly type II). Lower Cretaceous shales have a strong ability to generate oil in the Sinop Basin. Ekinveren oil seep is being observed in the southern part of the Sinop Basin. Carbon isotope analysis, biomarker ratio and oil-source correlation studies indicate that the Ekinveren oil seep is correlatable with Lower Cretaceous black shales in the basin. Albian aged sediments are well known in the Romanian offshore that have been one of the main reservoir targets for hydrocarbon exploration. Albian sandstones are composed of thick sand-rich proximal turbidite successions interbedded with siltstones and mudstones in Sinop basin. Channelized stratified sandstones and non-channelized massive sandstone layers of proximal channel turbidite and sheet-sands have poor to good quality reservoir properties. Sand to shale ratio is increasing within the lower part and decreasing in the upper part of Early Cretaceous succession in the Sinop Basin.

Conclusions

Potential reservoirs within the lower part of Early Cretaceous sedimentary package are represented by 20-30 m thick quartz-rich sandstone facies overlying the Late Jurassic shallow marine to platform carbonate units. The reservoir quality of the Early Cretaceous sand-rich facies is controlled by mainly depositional facies and diagenetic alteration in Sinop basin. The mineral composition of the turbiditic sandstones also has a major effect on porosity and permeability. The geochemical and mineralogical properties of Lower Cretaceous shales such as total organic carbon content, kerogene type and maturity, mineral content were analyzed in order to study the geological characteristics and possible unconventional potential of thick marine shale of Caglayan Formation. The Lower Cretaceous syn-rift deposits represent potential shale gas/shale oil play, due to its high organic richness, medium maturity levels. The shale has high quartz content (more than 40%). Shales are composed of 25-60% quartz grain, 3-10% feldspar, 5-20% calcite and 1-4% pyrite. The content of brittle minerals including quartz, feldspar, calcite and dolomite is up to 50% on average and the content of clay minerals is lower than 20% in Caglayan Formation (Figure 3).

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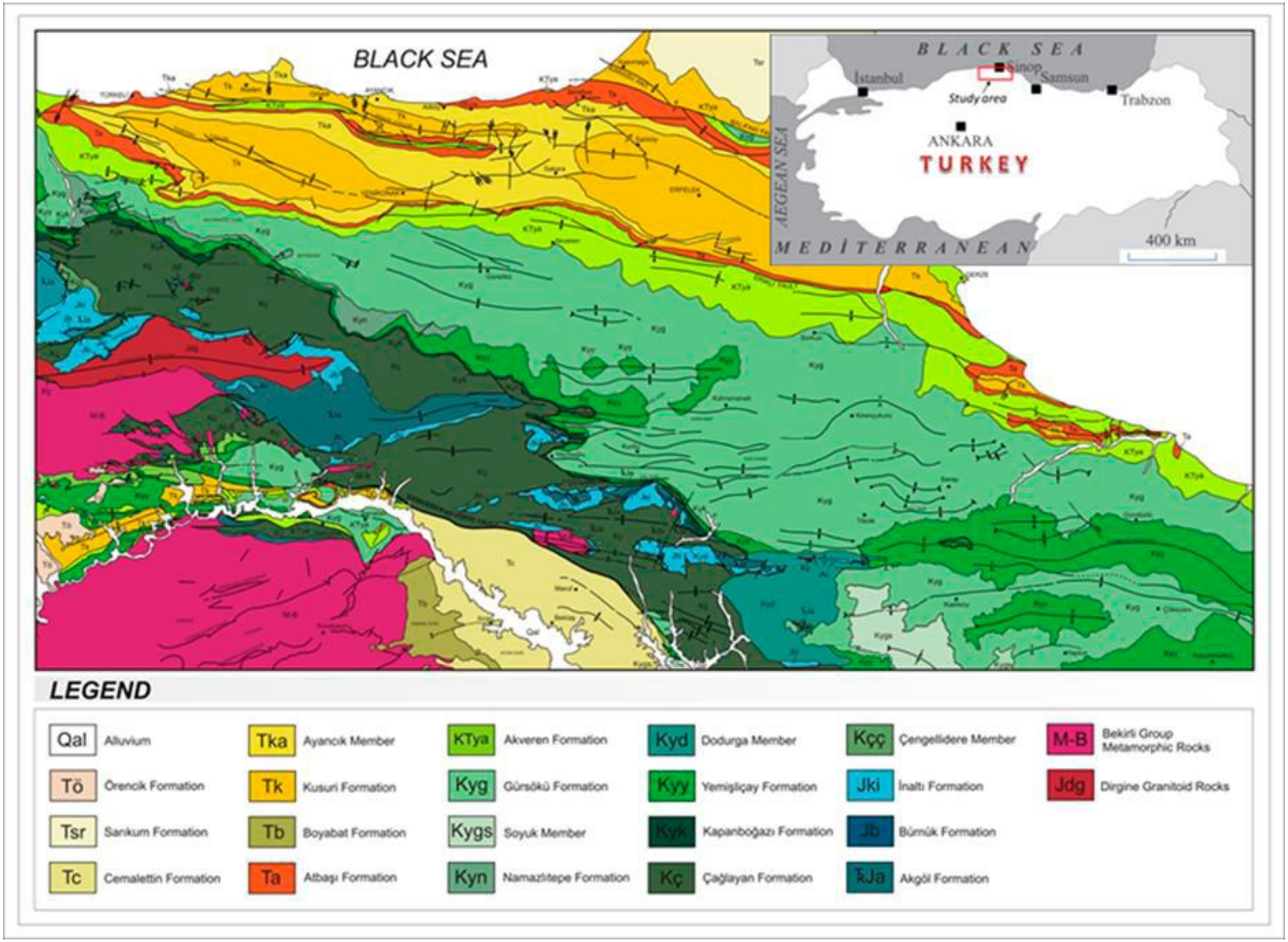

Figure 1. Simplified geological map of the Sinop Basin.

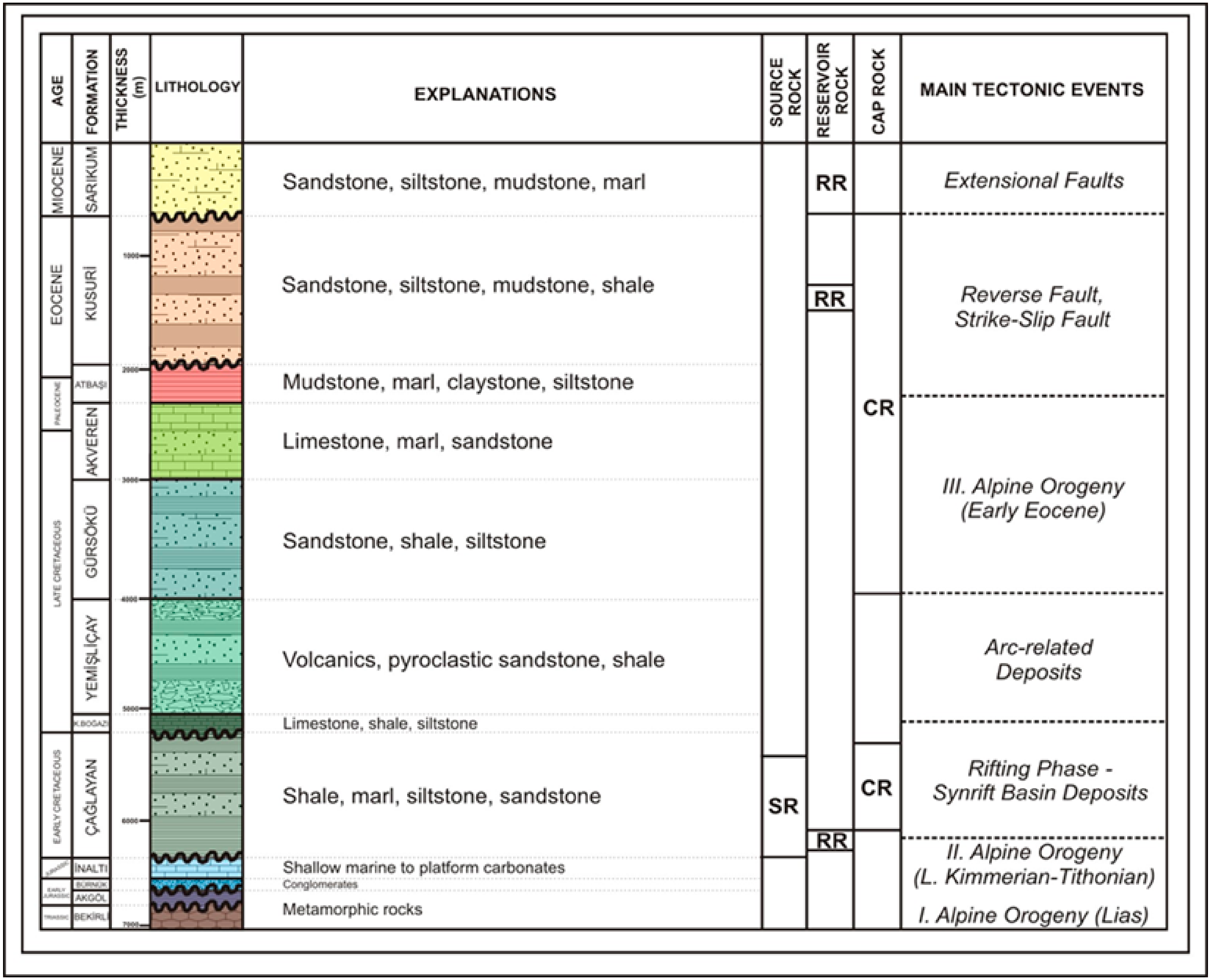

Figure 2. Generalized columnar section of the Sinop Basin.

XRD - Whole mineral composition (%)					XRD- Clay mineral composition (%)			
Quartz	Feldspar	Calcite	Pyrite	Total clay	Smectite	Chlorite	İllite	Kaolinite
63	-	eser	-	37	13,2	-	7,8	15,9
63	-	1	-	36	10,7	-	7,6	17,7
57	-	13	4	26	-	-	13,1	12,9
58	-	13	3	26	-	-	13,2	12,8
48	-	4	-	48	-	-	19,9	28,1
62	9	2	-	27	9,5	-	7,6	9,9
37	6	3	4	50	13,1	12,6	11,9	12,3
27	5	1	4	63	-	trace	30,2	32,8
22	6	1	1	70	24,9	trace	19,7	25,4
35	10	3	2	50	11,1	trace	15,7	23,2
36	8	8	4	44	9,5	11,6	9,4	13,5
42	6	7	-	45	15,2	trace	13,6	16,1
55	10	8	-	27	5,3	9,9	4,7	7,0

Figure 3. Whole mineral and clay compositions of Early Cretaceous shales in Sinop basin.