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The Academic Senate on 28 November 1989 resolved that the candidate had satisfied requirements for admission to this degree. This thesis represents a major part of the prescribed program of study.

PETROLOGY, DIAGENESIS, AND RESERVOIR POTENTIAL OF THE SURAT BASIN SANDSTONES WITH SPECIAL REFERENCE TO HYDROCARBON EXPLORATION

by

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CERTIFICATE OF ORIGINALITY

I hereby certify that the work in this thesis is original, except where acknowledged in the customary manner, and has not been submitted for a higher degree to any other University or Institution.

H. M. Hawlader

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March, 1989.

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ABSTRACT

The detrital composition of the Jurassic and Lower Cretaceous Surat Basin sandstones comprises a wide spectrum ranging from quartzarenite through sublitharenite and feldsarenite/lithic feldsarenite to feldspathic litharenite. The sandstones are subdivided into two petrofacies: quartzose having more than 50% QFR detrital quartz, and labile having less than 50% detrital quartz. The results of petrographic modal analyses illustrate the characteristically dual-provenance basin-fill pattern of the succession, namely, an andesitic magmatic arc to the east-northeast and a stable craton consisting of plutono-metamorphic terrains and sedimentary and silicic volcanic rocks in older basins and platforms in the flanking cratonic regions. The labile sandstones are derived from the magmatic arc which intermittently shed volcanogenic detritus into the subsiding foreland basin. Conversely, the quartzose facies received predominantly cratonic input (deposited during waning phases of magmatism in the arc and concomitant gentle rise of the foreland) with some additional sediments from the arc which presumably was dissected to varying degrees during these periods of relative tectonic quiescence. Sandstones of the whole Mesozoic succession in the Surat Basin comprise several petrologic cycles each of which begins with a craton-derived quartzose facies and ends with an arc-derived quartz-poor labile facies. These cycles reflect the episodic tectonic activity of the arc-craton couplet during basin evolution.

A study of the geologic evolution of sandstone reservoir characteristics suggests that compaction and cementation have both reduced primary porosity and permeability to an extent that is dependent on detrital composition and texture. On the other hand, subsequent

dissolution of framework grains and cement have created secondary porosity that is present in varying proportions in sandstones of all mineralogic compositions. Two mechanisms are thought to have been especially important in the development of secondary dissolution porosity in the Surat Basin sandstones: firstly, selective framework-grain and interstitial cement dissolution caused by organic maturation products emanating from intercalated mudrocks prior to the onset of hydrocarbon generation; and secondly, meteoric flushing of the basin consequent upon the inception of its artesian character (i.e., as a geographic component of the Great Artesian Basin) in the Tertiary.

Diagenetic clay minerals are present in all stratigraphic units, either as individual species or in preferred species associations, and invariably are found to have reduced porosity and permeability. Their effects on reservoir characteristics are a function of the abundance, mineralogy, crystallographic habits, and geometry of distribution of the clay within the reservoir. Some of the clay minerals are fresh-water- and/or acid-sensitive whereas others are prone to effect a mechanical migration-of-fines problem due to pressure-differential between the formation and the well during drilling, testing and hydrocarbon production. Furthermore, the presence of interstitial clays, whether detrital or authigenic, has drastically increased the proportion of microporosty while at the same time reduced effective (macro-) porosity - information about which phenomena is crucial for reliable estimation of hydrocarbon reserves.

The diagenetic clay minerals in the Surat Basin are found to follow certain stratigraphic and geographic trends: the relatively quartzose sandstones contain mainly kaolinite with some minor smectite, illite-smectite and chlorite whereas formations rich in volcanogenic detritus are characterised by smectite, mixed-layer smectite-illite, and minor kaolinite.

A quantitative study employing multiple regression analysis indicates that the present-day porosity of the Surat Basin sandstones is primarily a function of five variables; in order of decreasing importance they are the diagenetic cement, detrital mineralogy, geologic age, burial depth and depositional environments. The present study also confirmed in a quantitative manner the notion and observations of various workers that: in a retro-arc foreland basin, hydrocarbon reservoirs occur preferentially in the craton-derived mineralogically mature quartzose sandstones; and conversely, petroleum source-rocks preferentially comprise the arc-derived finer-grained lithic/labile volcanogenic rocks that are prone to be `tight' because of their greater physical and chemical reactivities. A literature survey of the Mesozoic Western Canada Basin indicates a similar pattern of association suggesting that the occurrence of hydrocarbons in retro-arc foreland basins probably follows this general pattern world-wide.

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