Structural Analysis and Prospect Evaluation of GS-1 Sand in Gandhar Area, South Cambay Basin, India

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Summary

The Gandhar Field has been one of the most prolific onshore hydrocarbon producers in India. An attempt is made to understand the occurrence and distribution of hydrocarbon in GS-1 sand in the north-eastern part of Gandhar field. An integrated study of available seismic, well and reservoir data has been undertaken and a sand distribution model is attempted integrating well data and acoustic impedance attribute. Detailed structural analysis of the area indicates that minor faults also play a major role in hydrocarbon entrapment in this area as the sands are thin, of the order of 3 to 6m.

Introduction

Cambay basin is one of the most extensively explored sedimentary basin of India. More than 90% of hydrocarbon reserves of the basin occur in Middle to late Eocene successions, which has been the main focus of hydrocarbon exploration in this region. The study area falls in Jambusar–Broach block of Cambay basin. The area lies on the north–eastern rising flank of Broach depression. Multiple reservoir sands of Hazad member of the Ankleshwar - Formation are hydrocarbon producers in this area. Sands of Hazad Members have been deposited in the form of different lobes, and hydrocarbon entrapments occur in structural, stratigraphic and stratigraphic-structural traps. The sand input is mainly from north and north-east. Sand GS-1, under study here is extensively developed in central Gandhar and pinches out towards west and north. In sand GS-1, hydrocarbon has been established in two major pools (central and southern block), and three small isolated pools. Most of the wells fall in central/western part of the area but a few wells namely B-A, B-B and B-C fall in north–eastern side of the field (Fig-1). These wells are hydrocarbon bearing from GS-1. Well B-D which was drilled for exploration of oil along an elongation of this sand, went dry though it had a good structural position. The very poor development of the sand warranted restudying the area integrating all geo-scientific data.

Reservoir model and play

Seven wells have been drilled in this area. The well B-B & B-C produced @ 32 m³/d oil with 9464 m³/d gas through 12mm bean and 42 m³/d oil with 7773 m³/d gas through 6mm bean size respectively from GS-1 sand. In well B-E, sand GS-1 is not developed while in B-F and B-G, sand GS-1 is present, but dry. To the north of the area, well B-A has encountered H/C in sand GS-1. Well B-H, showed 3 meter effective sand thickness and on testing, gave 2 cubic meter oil with water on initial testing and further gave 1 cubic meter of oil in second phase of testing. Another well B-I which is 62 meter structurally down with respect to B-

Fig.1: Time structure map near top of sand GS-1
drilling; however the well was not tested. Therefore the area between wells B-H and B-I is interesting for further investigation and delineation of prospects.

**Methodology**

The 3-D seismic data available in the area is reinterpreted. Attempt has been made to delineate even the minor structural variations and faults by studying various attributes like density, amplitude, instantaneous phase etc. An effective sand thickness map is prepared with the help of well data and this map is tied up with acoustic impedance attribute, along arbitrary seismic lines connecting different wells. Integrating all these data, prospectivity of the area is evaluated.

**Structural Interpretation of the Area**

For structural interpretation of the area under study, a reflector, timely equivalent to top of sand GS-1 is picked up and a time structure map is prepared (Fig-1). Analyzing the seismic character, it is found that the area consists of very small structural variations with highs and lows of very small dimension. These variations are clearly seen by applying seismic attributes like instantaneous phase.

A good number of NS trending normal/reverse faults along with antithetic faults are seen in this area. These faults are separated by EW trending transfer faults. The fault pattern reveals that the area has been subjected to polyphase deformation. It is observed that some faults cut across each other and take sudden swing. These faults divide the area into different blocks, with different fault pattern. For example the nature of fault near well B-D (dry well), is quite different from the faults in neighboring areas, i.e. near the wells B-A, B-B and B-C (all producing). Seismic section with fault pattern across the well B-D is shown in fig-2. An impedance section also confirms the existence of this type of fault.

The fault changes its orientation in south direction near the well B-H. Structural style near this well is resembled to the structure of wells B-A, B-B or B-C (all are producing). It is interesting to say that this well showed traces of oil on testing. An impedance section showing the structural style of well B-H is shown in fig 3 and a seismic as well as impedance section passing through the hydrocarbon bearing well B-B is shown in fig-4 Both of these figures depict the structural position of these wells. An open area of similar structural style is left towards higher position of well B-H in the same fault block as no well has been drilled here till date.

An area of similar fault pattern is also seen in another block to the north of B-H well (Fig-5.) This block is structurally higher than the block of well B-H. Structure
An effective sand thickness map is prepared with the help of well log data. Attribute analysis (acoustic impedance) of 3-D seismic data falling in this area is also attempted to know the hydrocarbon occurrence of the area. For this purpose a few arbitrary lines of acoustic impedance attribute, connecting with the wells of different direction, are taken. Effective sand thickness and hydrocarbon occurrence of the wells falling on these lines are correlated with the values of acoustic impedance. On this basis sand distribution pattern is decided.

From the study, it is found that the wells falling in higher range of acoustic impedance have hydrocarbon bearing sands while wells falling in the range of very high acoustic impedance are devoid of hydrocarbon. Impedance values less than 30200 are found to be poor quality reservoirs having poor performance from hydrocarbon point of view. An arbitrary impedance line passing through SWS-NEN direction, across the well B-H, B-B & B-E is shown in fig-6. It is clear from this figure that the area towards north-east direction to the well B-H is having a good amount of sand as the values are matching with the values of producing well B-B while the area south of well B-H is devoid of hydrocarbon bearing sands as the impedance value is lower in this direction. Another arbitrary line across the well B-E (Dry well) along NWN-ESE direction is also taken for study (Fig-7). Values of acoustic impedance is this direction is matching with the values of dry well B-E, in a nearby area, however its values are changed towards north and south direction, showing the sand entry from north and south of well B-E, as shown in fig-8. Area around B-E is devoid of hydrocarbon bearing sands. It is also observed that the well B-E is falling on the local lows, and hence dry. A good number of arbitrary lines are taken in different direction and sand distribution pattern along with sand pinch-out is predicted. The sand distribution map so obtained is shown in fig.8

The model shows that the maximum thickness is in the order of 4 to 5 meter with the sand entry from north-east. The Impedance map shows that the area around well B-H has good sand development.

**Conclusions**

Hydrocarbon occurrence and sand distributions of GS-1 sand in Gandhar area is very much affected by small
structural variations and different types of faults occurring in this area. Local lows and highs also play a significant role in this regard. Acoustic Impedance attribute is a very effective tool for predicting the sand distribution pattern and hydrocarbon occurrence. The sand model prepared with impedance analysis may be helpful for predicting the lithology and hydrocarbon distribution pattern. Area north east of well B-H seems to be prospective from exploration point of view.

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