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Potential Evaluation of Underexplored Play in Matured Field – A case study of Rudrasagar Field, Assam

C.Samajdar*, Bhaskar Morang, M.V.Ramana, JyotiBorthakur
Oil & Natural Gas Corporation Ltd A&AA Basin, Jorhat, Assam

Summary

*Rudrasagar field of North Assam shelf is one of the oldest field of India and first discovered field in Eastern India. The Field was discovered in 1960 and put on production in1966 from 12 wells. Hydrocarbon accumulation is confined mostly to the topmost part of arenaceous unit of Barail group sand of Oligocene age named as Barail main sand (BMS), which is the main pay in the field. The main BMS pool has been dissected by faults into five blocks, viz. Block-I- IV and Block -145 in the southern part. Beside BMS, sands within Barail Coal Shale (BCS) of Oligocene age and Tipam sand (TS- IV – Miocene) also have contribution to oil production of the field. The TS-IV sand have been found commercially hydrocarbon bearing in two wells (**W-A&W-K**) within Rudrasagar main field and **W-G** in North Rudrasagar Field. Analysis of encouraging log signature integrated with other data indicates presence of hydrocarbon in this sand in other areas of the field. But these TS-IV sands are discrete and thinner as compared to nearby Charali- Changmaigaon area. The present paper discusses the possible exploration/development targets in TS-IV sand in Rudrasagar and North Rudrasagar area with integration of all geoscientific data.*

Introduction

Assam shelf is a polyhistoric basin with basin evolution is intricately linked to movement of Indian plate from Cretaceous to present and its collision with Eurasian and Burmese plate. Basin fills are imprinted with signature of rifting, drifting and subsequent collision with Tibetan and Burmese plate. The Study area along with the generalized stratigraphy of North Assam Shelf is shown in Fig.1.

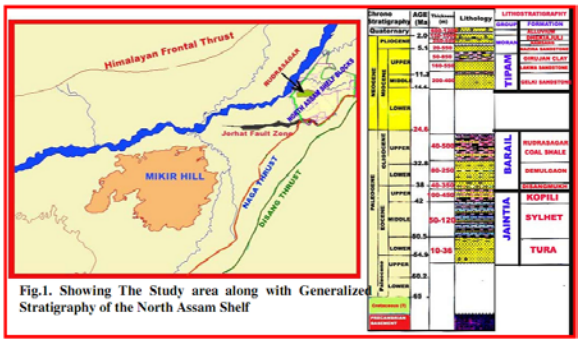

Fig.1. Showing The Study area along with Generalized Stratigraphy of the North Assam Shelf

Rudrasagar Field of North Assam shelf was the first discovered field by ONGC in NorthEast in 1960. The main reservoir in this field is from Barail Main Sand (BMS) of Oligocene age. Beside this main pay of BMS, sands within Barail Coal Shale (BCS) and Tipam Sand (TS-IV sand) have hydrocarbon occurrence in few wells. Production from BMS is now in declining stage. At this matured age of the field, other pays of the field needs reevaluation for supplementing the declining production from BMS. Tipam sands (TS-IV/V) which are the main producer in nearby CharaliChangmaigaon area, may have significant potential in the area. But presently this sand is producing hydrocarbon from only one well in the field whereas other two wells in nearby area are commercially hydrocarbon bearing. Within the thick Tipam sequence TS-IV sand unit is sandwiched between Lower clay marker (LCM) and TS-V. Due to limited production from three wells coupled with complexity of sand distribution vis-à-vis strati-structural entrapment situation makes the Tipam exploration in Rudrasagar field challenging. Even after commercial production of hydrocarbon from three wells and drilling of around 175 wells in the field (for BMS sand), distribution of hydrocarbon in TS-IV sands is yet to be understood for exploration and development.

A& AA Basin, North Assam shelf Block, LuitBhavan, Jorhat Assam Email : scs_cal1@yahoo.com

In the present study an attempt has been made to understand the distribution of TS-IV sand and their suitable locales for hydrocarbon entrapment in the area.

TipamSands – Its Depositional Style

In Upper Assam the Tipam Group is unconformably sandwiched between the Barail Group and the Namgsang formation. The massive arenaceous unit of Tipam Group is known as Tipam Sandstone Formation. The different units of these Miocene sands are prolific producer in almost all the discovered fields (viz. Lakwa, Gelki, Charali, Changmaigaon) of North Assam shelf except Disangmukh and Panidihing area. Overall, the sands are of fluvial in nature and composed of thick moderately coarse ferruginous sandstone with some alternations of blue and mottled clay, mudstones, shaly sandstones and sandstones. From top to bottom, the sand units of TS-I-II are separated by very thin units of clay/shale pack. Whereas the TS-III and IV are separated by a reasonably thick clay/claystone pack with intervening channel fill sandstone of flood plain origin as Lower clay marker (LCM). The topmost sand unit (TS-I) is capped by a regional clay maker named as Girujan Clay Formation of Tipam Group.

TS-IV sand is hydrocarbon bearing in well W-G (in North Rudrasagar) and W-K and W-A in Rudrasagar main field. The sands are non-resolvable in seismic data, masked in the prominent LCM (Lower Clay Marker) reflector. Typical log signature of TS-IV sand is shown in Fig.2.

The LCM represents a major distinctive fluvial clay marker throughout North-Assam shelf. These flood plain deposits are sandwiched between TS-V and TS-III sands.

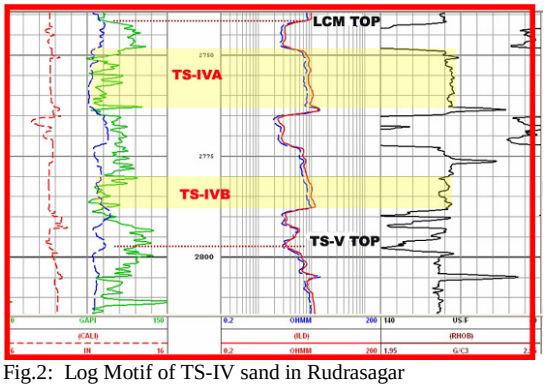

Fig.2: Log Motif of TS-IV sand in Rudrasagar

The deposition of TS-IV sand within LCM flood plain occurred as fluvial channel mostly anastomosing at places, forming meandering channels as the slope decreases. The channels are guided by paleo relief of the area which was subsequently changed due to later tectonics. Rudrasagar area was a paleo high during deposition of these sands, hence in this area, the thickness of TS-IV/V sands is less compared to nearby Charali-Changmaigaon field which were low at the time of deposition. The structure of Charali- Changmaigaon was later raised due to subsequent plate movement which led to compressional tectonics (over pre-existing extensional tectonics). Moreover pre-existing lows with in Rudrasagar field which were subsequently raised due to later tectonics can be the good target for Tipam exploration. In this paper these targets for exploration have been identified and more emphasize has been given for delineation of reservoir facies of TS-IV sand as it is a major concern for its discrete nature.

Main Challenges for the study

- Producing wells of TS-IV sand viz**. W-G, W-A** and **W-K** fall in the area where seismic data is either absent or falls in low foldage zone which makes well seismic calibration uncertain.
- Since the main producer of the field is BMS, most of the sidewall and conventional cores are confined to that zone only. Detail analysis of SWC are mostly not available for TS-IV/V zone.
- Density and Neutron porosity logs in TS-IV zone in older wells are also absent which makes the situation more complicated for petrophysical studies.

Solution *Total Petroleum system analysis for TS-IV sand by integrating all the available geoscientific data of the field*

Present Status of Exploration of Tipam sands in Rudrasagar

As stated above, TS-IV sand is commercially hydrocarbon bearing in **W-K**, **W-A**, and **W-G**. The first core cut was in 1960 in well **W-A**in TS-IV/V sand and was oil bearing. Subsequently the well **W-AA** was drilled and astonishingly that equivalent sand was absent in this well which is few meters away from **W-A**. This shows the complicated nature of TS-IV sand geometry of the area. Beside this logs of well **WP** (in the northern part), **W-M**, and **W-N** (in North Rudrasagar) were interpreted as oil bearing in TS-IV zone.

In the western part well **W-F** was tested and found water bearing. Eight other wells viz. **W-B**, **W-C**, **W-D**, **W-E**, **W-H**, **W-I**, **W-J** and **W-L** were tested in Tipam sands in different parts of the field with all found to be water bearing. This paper explains why these tested zones were water bearing and where the better locales are still available for exploration/development. Fig.3 shows the location of these wells in the field.

Fig.3: Basemap Showing location of the Wells

It includes the analysis of all the wells and 3D seismic data to evaluate the prospectivity of TS-IV sand. The structural disposition has been shown in log correlation of TS-IV sand in N-S and E-W direction (Fig.4 & 5).

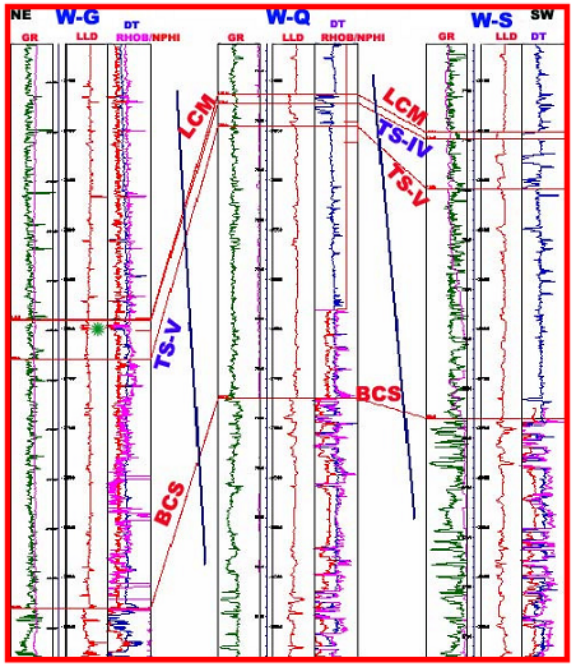

Fig.4. NE-SW Log Correlation showing TS-IV & V Pack

Study of well logs indicates the TS-IV sand is genetically fluvial in nature and at places the sand is absent abruptly. It is in contrary to producing deltaic BMS sand in the area which is present all through the shelf area. In the study area more than 150 wells have been drilled which has been analyzed and a structure contour map has been prepared on top of TS-IV. The structure contour map shows four prominent closure areas in eastern, central and western part of the field.

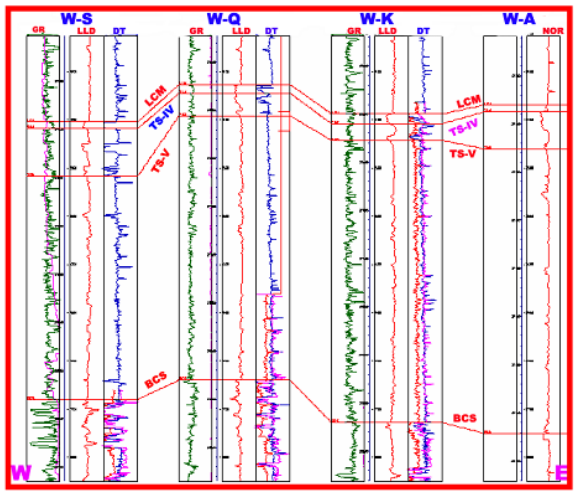

Fig.5. SW-NE Log Correlation showing TS-IV & V Pack

After identification of structural closures the sand isolith map of TS-IV sand has been prepared which shows NE-SW trending channel morphologies. From this map the main reservoir areas have been demarcated and superimposed on TS-IV structure contour map. This map shows the areas with good structural entrapment as well as good reservoir unit (Fig.6). Since TS-IV sand units are not resolvable in seismic data, in order to estimate the pack thickness of TS-IV sand where well density is less seismic attribute studies have been carried out. Instantaneous frequency derived between LCM and TS-V shows that a relationship between instantaneous frequency and pack thickness exist in the field (Fig.7).

It is found that *'lower the frequency higher the isopach thicknesses and vise versa'*. The Instantaneous frequency 1520 Hz when calibrated with isopach map it corresponds to 50m pack thickness. This map can be used for estimating the TS-IV pack thickness in southern and eastern part of the field where the well density is relatively less.

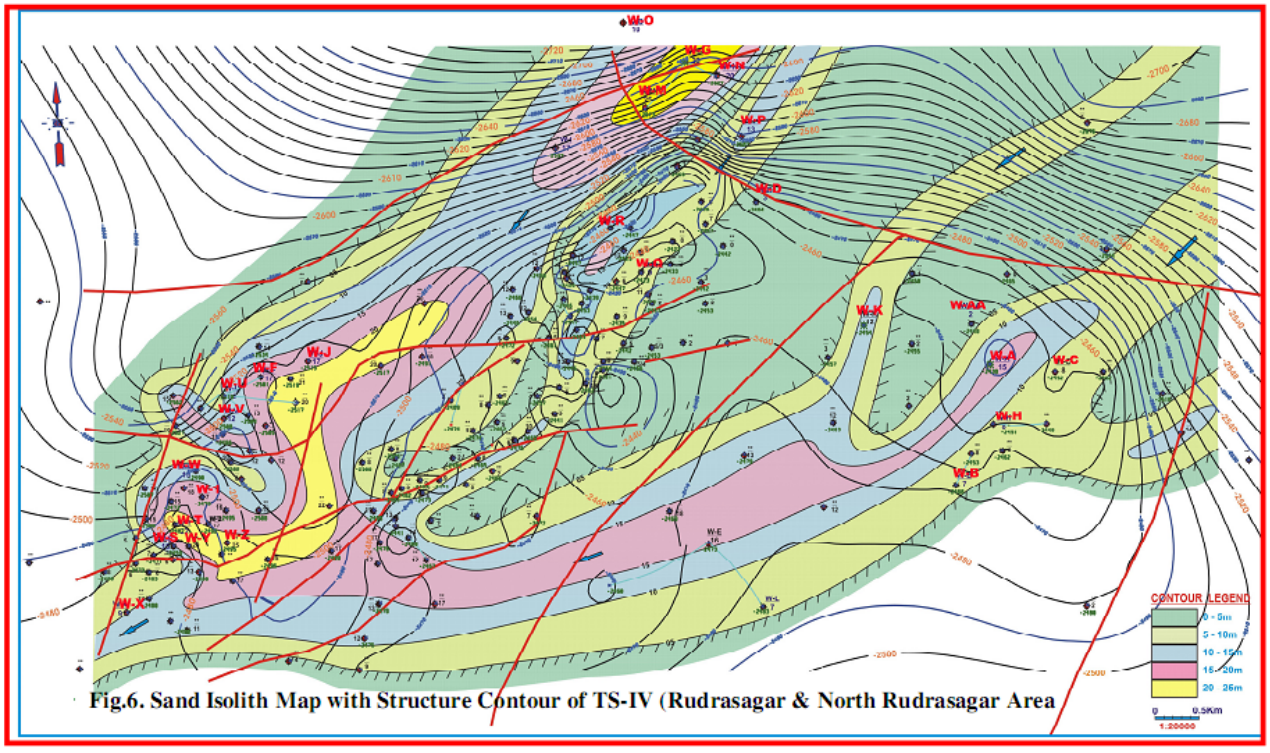

Fig.6. Sand Isolith Map with Structure Contour of TS-IV (Rudrasagar & North Rudrasagar Area

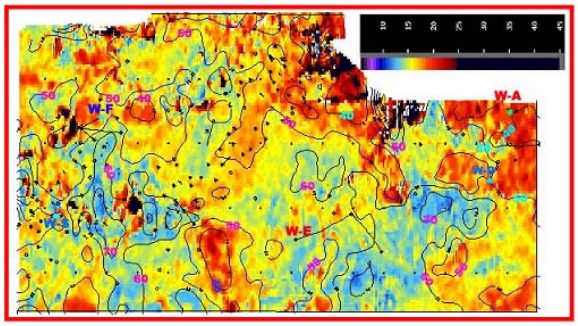

Fig.7. Instantaneous Frequency between LCM & TS-V with Isopach

On analyzing Fig.6, it is evident that oil occurrence of W-A can be attributed to the good reservoir sand development in the area along with a four way structural closure. Well **W-AA** drilled very close to it is almost devoid of reservoir facies. Similar structural closures exist in central and western part. It is observed that in the eastern and central part the lower sand unit of TS-IV pack (TS-IVB) is hydrocarbon bearing, whereas the log evaluation indicates presence of hydrocarbon in the upper sand unit (TS-IVA) in the western part.

In the Central part two prominent structural closures have been brought out by structural mapping. The southern most closure falls in the poor reservoir facies zones, and hence ruled out for any hydrocarbon entrapment. The logs of the TS-IV sands within the closure also support the above conclusion.

The northern closure in the central field shows good sand development as well as presence of good entrapment situation. The log reevaluation of well **W-Q** shows Sw around 66%. Well **W-R** towards north also indicates presence of liquid hydrocarbon on log interpretation. 3D seismic data partially covers the area which also confirms the presence of structure in at this level in the area.

In the western part, one structural closure has been identified with locales of good sand development. Among all the identified closures this one seems to be the most promising. In the same closure well **W-S** was drilled for BMS in which GYF and mild cut was observed in TS-IV section. A well profile has been drawn across this western most closure (Fig.8) which shows the change in the resistivity log signature with structural disposition. From north to south it is evident that resistivity is high within the structural closure whereas the resistivity is decreases for TS-IV pack outside the closure.

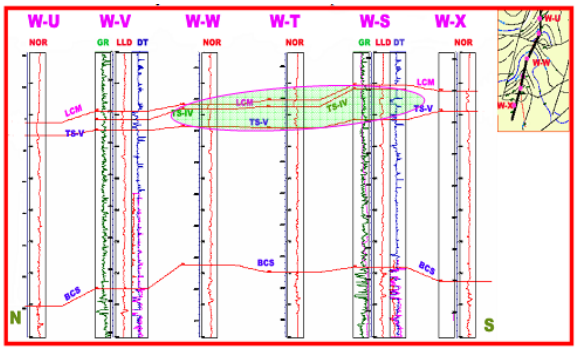

Fig.8. Log Profile Showing Resistivity variation in & out of Structure

Log profile in E-W direction across the structure, also confirms the similar result and indicates presence of different fluids in TS-IV sand in and out of the closure.

ELAN processing of well **W-S** also shows the presence of movable hydrocarbon (Fig.9).

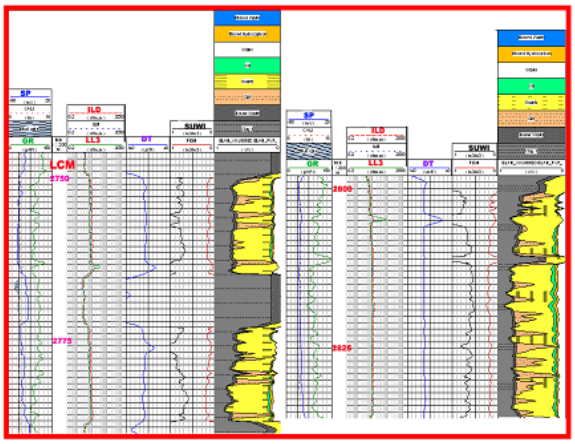

Fig.9: ELAN processing of well W-S

Some more promising log signatures of TS-IV/V pack in the western and central part have been shown in Fig10A & 10B respectively.

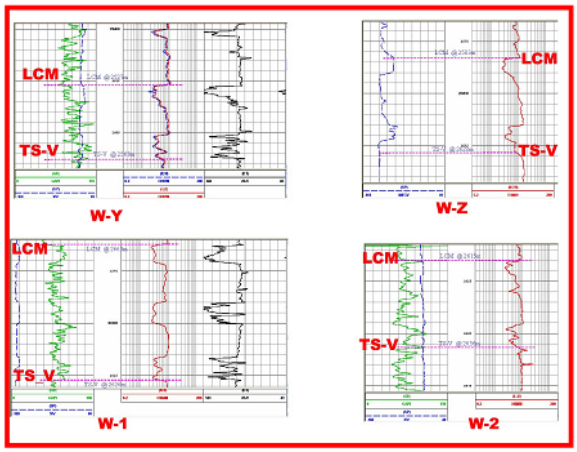

Fig.10A. Log Signature of Western Part

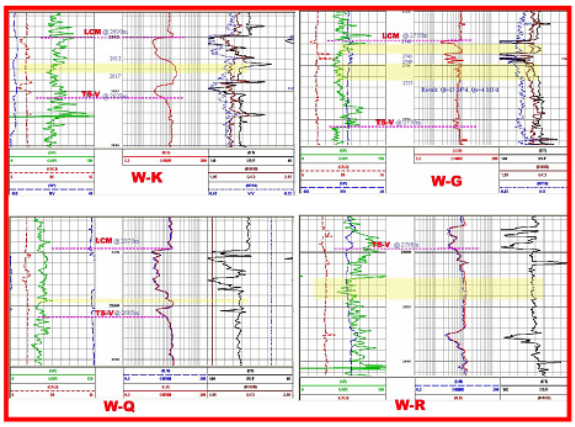

Fig.10B. Log Signature of Central Part (Rudrasagar& North Rudrasagar Area- - W-G & W-K are oil producer from TS-IV)

Analysis of the Wells Tested in Tipam

Following table shows the testing results of all the tested wells in Tipam sands in Rudrasagar Field

	Interval(m)	Testing Results
W-B	2573-2563m(TS-IV)	Water with salinity 1.778gpl
W-C	2575-2579m (TS-IV)	Water with salinity 1.29gpl
W-D	TS-IV	Water bearing
W-E	TS-1 perforated 2026-30m	Water bearing
W-K	**2612-2617, TS-IV**	**Oil @22 m^3/d with 12% water cut.**
W-G	**2746-2749, TS-IV**	**Oil @2m^3/d with 76% water cut.**
W-A	**2556-2562, TS-IV**	**Oil @2m3/d with 98% water cut.**
W-F	2715-2725m TSIV	Water bearing
W-H	2621-2624m YS-IV	Water bearing
W-I	2871-74m 2724-26m 2721-24m	Water with salinity 1.2 gpl Water with salinity 1.52gpl
W-J	2632-38m	Water bearing
W-L	2807-09m 2815-17m 2821-24m	Water with salinity 3.2gpl (*TS-I/II*)

Among these wells well W-B located in the eastern part, is having net sand thickness of around 7m, but structural closure is not conclusive from the available data. Similar is the case for wells W-C and W-H where the structural entrapment could not be ascertained with present dataset. As it was mentioned earlier, in the eastern part well W-A is having confirmed structural entrapment along with good sand development (~15m) and it is oil bearing. Wells W-I, W-J are found to be water bearing as entrapment situation is doubtful. Well W-F tested in TS-IV is also found water bearing. The well may be below OWC/OSC of TS-IV sand. The identified locale in the western part is around 35m higher than the well W-F.

Oil in Tipam sands in well **W-G** indicates migration of oil in TS-IV sands towards North Rudrasagar area. Similarly the drilled well **W-O** (drilled for Pre- Barail) further north of the area shows favorable log signature in TS-IV sand. The North Rudrasagar area also seems to be promising for exploration of TS-IV sand.

Petroleum System

Source rock	Shales within BCS, Kopili
Entrapment	Fault/ Four way closure
Reservoir	Channel sands
Seal	Clays within LCM - As encountered in Producing wells. Thickness of clay pack is around 10m.

On the basis of the study it is found that all the components of petroleum system are present within the identified Western and North-Central structural closure within the study area. These should be the future exploration target for Tipam sands in Rudrasagar area. Among these two locales westernmost seems to be most prospecting considering the GYF/mild cut in TS-IV section.

Moreover the zones of TS-IV in North- Rudrasagar area in and around drilled well **W-O and G** also to be chased as GME model is also satisfied here with promising log signature and presence of oil in **W-G**.

Conclusions

- The study shows, TS-IV sand holds good potential for hydrocarbon inRudrasagar field.
- Analysis of well data integrated with seismic data brings out two possible locales for hydrocarbon entrapment in the area. The westernmost area is more prospective part as direct evidences have seen in this part.
- In the western part, increase of resistivity indicates presence of hydrocarbon within the structure which is also indicated by ELAN processing of Well W-S. Similar signatures are also observed in the other wells of the area.
- In the Central part, TS-IVB sands and part of TS-V sand seem to be more promising compared to TS-IVA. This locales should be tested only after the western locales are found to be hydrocarbon bearing.
- North Rudrasagar area especially the areas around well **W-G**, **W-O** should be carefully evaluated for testing as this area also holds the good hydrocarbon potential for TS-IV sands.
- Integrated approach for analyzing the observed results considering the Petroleum system of the area for TSIV sand may yield better results for identification of testing zones.

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(Ideas & Views expressed in this paper are solely of the authors. The organization may or may not have similar views about the same.)