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Deeper Plays in Bombay Offshore Basin: A Renewed Exploration Thrust

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Summary

The deeper exploratory plays are presently considered as one of the thrust areas of exploration in Bombay Offshore Basin. These include Paleocene-Early Eocene clastic play, Paleocene-Early Eocene carbonate play, Fractured basalt play and possible Basin Centered Gas Accumulations (BCGA) in the basinal lows. Hydrocarbon accumulation in the deeper sequence is mainly strati-structural, controlled both by the development of reservoir facies, its continuity and the structural configuration. Unconventional plays like fractured basement along the Eastern Homocline and possible Basin Centered Gas accumulations (BCGA) are also envisaged in the Daman low and Central graben. The rising flanks of Daman low, Navsari low, Diu depression, Central graben and South Bombay depression would be encouraging for the deeper plays. The major challenges in exploration of deeper plays include geological modelling of the deeper plays, seismic imaging and mapping of the thin and discontinuous sands, combating high pore pressure and establishing the unconventional plays like Basin Centered Gas Accumulations (BCGA). Intensive adoption of new technologies for imaging deeper plays, sound well completion technology for handling HPHT related problems and modern electro-logging suites including LWD has to be hastened for exploration and exploitation of deeper plays.

Introduction

Exploration for deeper plays has been one of the recent thrust areas of exploration activities in Bombay Offshore basin. The earlier exploration efforts were mainly concentrated to shallower structural and stratigraphic plays in the post rift sequence. However, at present the focus is being shifted to the exploration of deeper plays within Syn-rift sequence in the basin. The Bombay offshore basin is a passive margin basin on the continental shelf of western India. The entire shelf area is affected by a series of basement controlled NW-SE to N-S trending faults, resulting in horst-graben morphology. The basin is divided into six blocks on the basis of tectono-stratigraphic considerations, viz. Tapti-Daman, Diu, Heera-Panna-Bassein, Ratnagiri, Bombay High-DCS and Shelf Margin blocks (Fig.1).

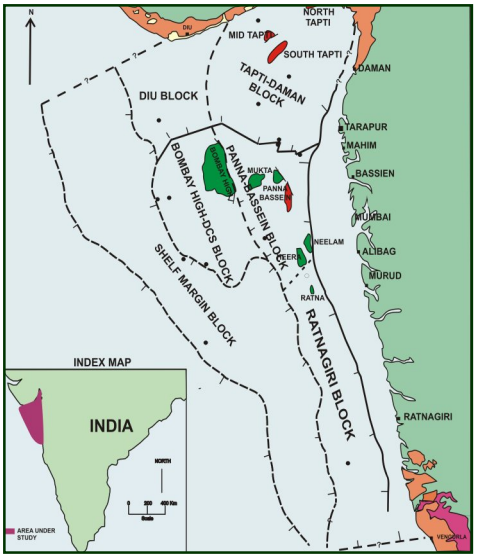

Fig.1. Map of Bombay Offshore Basin showing different blocks

The sedimentation in Western continental margin of India is governed by syn-rift phase (extension) and Post rift (thermal subsidence) phase (Jokhan Ram et al, 1998). The early phase of basin development marked by syn rift tectonism is characterized by development of number of grabens and half grabens, which control the distribution, thickness and geometry of syn rift sequences. The syn-rift phase witnessed deposition of texturally and compositionally immature sediments comprising coarse grained sandstone and conglomerates at the toe of fault scraps as alluvial fans filling the initial depressions and lows during Paleocene. It was followed by wide spread marine transgression during the late rift/ post rift phase. Two hydrocarbon bearing megasequences i.e. Syn Rift and Post rift sequence are identified in the basin. The litho-stratigraphy of the Bombay offshore is given in figure 2.

Deeper Plays

Number of accumulations of oil and gas are already known within the Paleocene-Early Eocene sequence at a relatively shallower depth in east and south-east of Bombay high, Heera- Panna Bassein platform and Ratnagiri block. However the deeper plays occurring at a greater depth are yet to be established on a bigger scale. These are far more challenging in terms of exploration and drilling, as they occur mostly in overpressured formations. Presently considerable attention is being given for exploration of deeper plays with a renewed thrust. The various deep exploration plays in Bombay Offshore basin are Paleocene-Early Eocene clastics plays, Paleocene- Lower Eocene carbonate plays, Fractured Basalt/Olpad equivalent and possible Basin Centered Gas accumulations in the basinal lows.

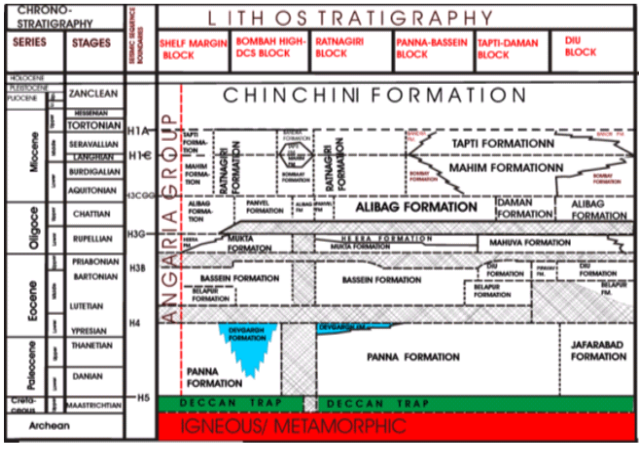

Fig.2. Lithostratigraphy of Bombay offshore basin (after Zutshi et al, 1993)

Paleocene-Early Eocene Clastic Play

The Paleocene-Early Eocene sequence is represented mainly by sandstone, siltstone, shale and coal along with carbonates. The sequence is divisible in to three major units from bottom to top: viz. - Lower, Middle and Upper units, based on litho-association. The electro log correlation with datum as Panna top (Paleocene-Early Eocene sequence top) across the south central graben in the Heera-Panna block brings out the sub-division of three units and their litho-facies within this sequence (Fig.3).

The Lower unit overlying the Cretaceous Deccan Trap comprises of material derived from the Deccan trap basalts (Trap wacke/wash) in the bottom part and inferred to be deposited in a fluvial / palludal environment. The upper part of this unit consists of alternations of siltstone/ sandstone and shale (reddish brown). The sandstone is fine to coarse grained, poorly sorted and contains feldspars. The grains are angular to sub angular, mainly rock fragments indicating their possible deposition as fanglomerates. The Middle unit consists of alternations of sandstone, siltstones, limestones, carbonaceous shale and coal deposited in a coastal swampy- marginal marine environment. The Lower unit is distinguished lithologically from the Middle unit by the absence of coal. The Middle unit is distinguished by presence of more sandstone and coal. The Lower and Middle units represent the syn- rift sequence. The Upper unit comprising mainly shale is associated with a transgression and constitutes the post rift sequence. The Lower unit is mainly confined to the pronounced depressions with depocentres aligned along the present day coastline (Mishra et al, 1997).

The Middle and Upper units are more widespread compared to the lower unit. The sequence varies thickness from non-deposition to about 2500m in the major depocentre. The major depocentres of Bombay Offshore basin are Daman low, Navsari low in Tapti-Daman area, Central Graben in Heera-Panna block, Vijaydurg graben in Ratnagiri area and South Bombay depression in Bombay High-DCS platform.

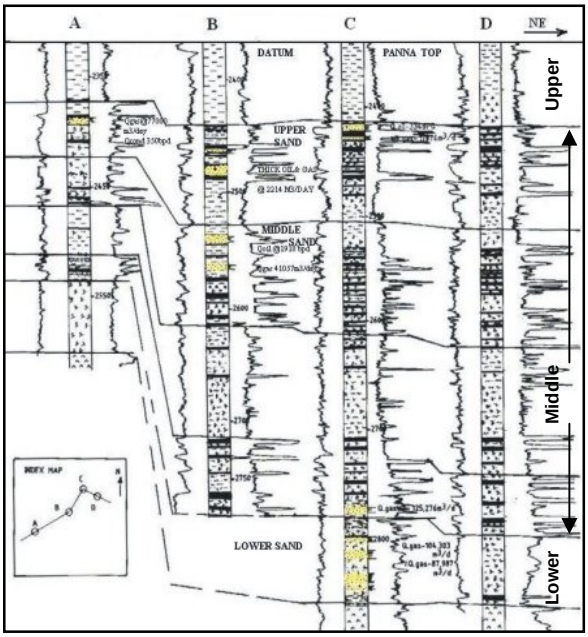

Fig.3. Electro-log Correlation of Paleocene-Early Eocene sequence across southern part of Central graben

In Tapti- Daman block the sands within the middle unit of the Paleocene- Early Eocene sequence are fine grained associated with siltstone, coal and minor limestones and show number of coarsening up cycles in the East Daman and Navsari low area. The unit grades to sandy facies towards north-west in the Saurashtra homoclinal part.

In the eastern part of Heera-Panna block, the sands within the middle unit are fine to medium grained, interbedded with shale, silty shale, carbonaceous shale and coal, which were deposited under marshy and swampy coastal part. Towards the south-western part, the sequence comprises sandstone, siltstone, limestone and coal. In the Panna- east and Bassein-east area the sands of the middle and lower units are associated with various lithofacies viz. siltstone, shale, sideritic mudstone and coal (Rai et al 2004).

In the area flanking the major lows like Central graben the thick sands of the lower unit are coarse grained to conglomeratic alternating with thin shales and have cylindrical log motifs. The isopach map of Paleocene-Early Eocene sequence in south central graben area (Fig.4) shows thickening towards north indicating sediment input direction towards north in central graben area.

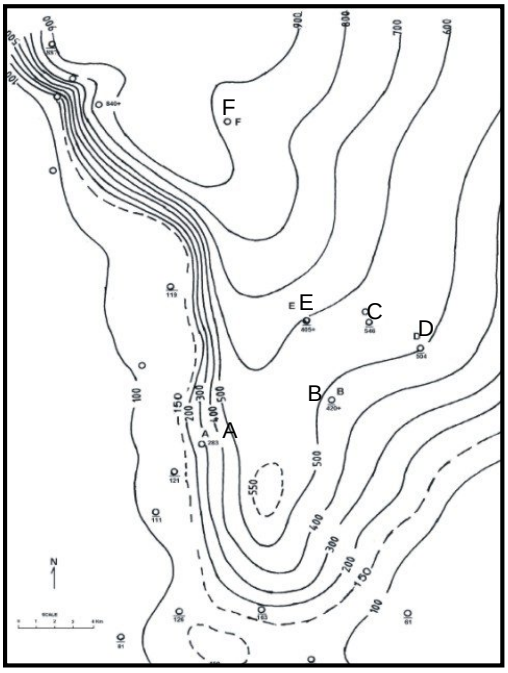

Fig.4. Isopach map of Paleocene-Early Eocene sequence in South Central graben, Heera- Panna- Bassein block

In the adjoining flanks of Bombay high the sequence comprises of fine to medium grained, poorly sorted, quartzitic, feldspathic, moderately porous argillaceous sandstone. The sands grades to conglomerate towards bottom part and are thought to be deposited as fluvial sands.

The lithofacies and reservoir characteristics vary considerably in different blocks. The sands are probably derived from the granitic inliers within the Bombay Platform, Mukta-Panna-Bassein paleo-high, and the Heera paleo-high. The sandstones are most commonly either basement-derived arkoses and sub-arkoses or litharenites, frequently with a high percentage of volcanic clasts.

The sand dispersal pattern within Panna sequence in the central graben area from 3D seismic attributes indicate fan/ fluvial channels as the main process for deposition with inputs from west and south-west (Biswal, S.K. et al, 2006). The sweetness attribute within 0 to -20 ms window with reference to Middle Panna shows high values oriented in channel like features (Fig.5). The 3D voxel image of upper Panna shows Fan features in western part and meandering channel features in central part (Fig.6).

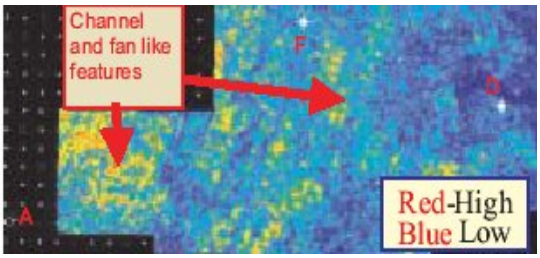

Fig.5. Sweetness attribute of Middle Panna (after Biswal et al, 2006)

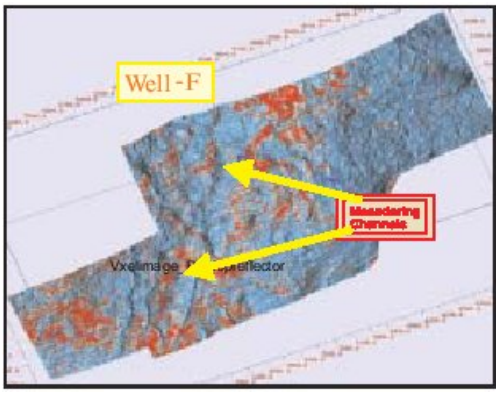

Fig.6. 3D Voxel image of Panna top reflector showing channel like features (after Biswal et al, 2006)

Recent exploratory efforts in the area to the south-west and north-west of Bombay High in DCS block and Ratnagiri block have produced significant oil and gas and provided impetus to the exploration of deeper plays. Hydrocarbon accumulation is governed both by the development of reservoir facies, its continuity and the structural configuration i.e. strati-structural entrapment for the accumulation. In some cases hydrocarbon accumulations are mainly stratigraphic plays associated with wedge outs, pinch outs, intertounging and shale out features flanking the Panna- Bassein platform and rising flank of Central graben. The clastic fans on hanging wall close to the major fault deposited as alluvial fans, fan deltas, channel sands in fluvial deltas in the major depocentres and coastal clastics are hydrocarbon bearing with entrapment situations like structural closures, fault closures and nosing features. Thus, strati-structural accumulations are the main plays in this sequence. The geological section across the southern arm of Central graben in Bassein- east area shows the structural disposition, litho-facies variation and strati-structural hydrocarbon entrapment (Fig. 7).

The Paleocene-Early Eocene Clastics strati-structural Play would be very encouraging in the rising flanks of Daman low and Navsari low. The western and northern rising flank of Daman low would be particularly interesting in view of encouraging results obtained in this area. The area close to Diu fault in both in Panna-Bassein and Bombay high-DCS blocks, rising flanks of Central graben would also be encouraging for the deeper plays. The southern part of Bombay high-DCS block having stratigraphic plays in the clastics and carbonates within the Paleocene-Early Eocene section would be a promising area for hydrocarbon exploration of deeper plays.

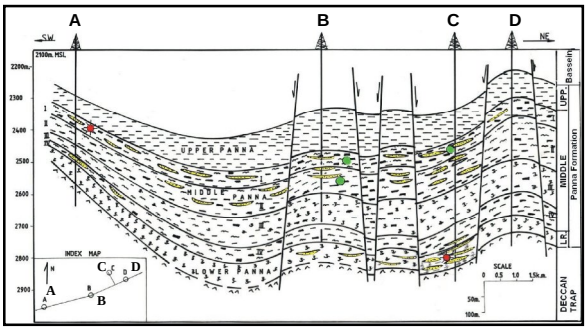

Fig.7. Geological section across southern arm of Central graben

Paleocene- Early Eocene Carbonate Play

The occurrence of Paleocene carbonates over the basinal high/basement high is another deep exploration play to be pursued in view of its encouraging exploratory leads obtained in the north-eastern part of South Tapti field. The play is basically carbonate body over basement high as a carbonate build up? showing good porosity and hydrocarbon shows. The seismic section shows the carbonate body over the basement/Trap (Fig.8). The H4 reflector corresponds to top Early Eocene (Panna top) and H5 reflector is within Paleocene-Early sequence. This sort of carbonate body over the paleohighs could be encouraging for pursuing exploration for carbonates in other areas.

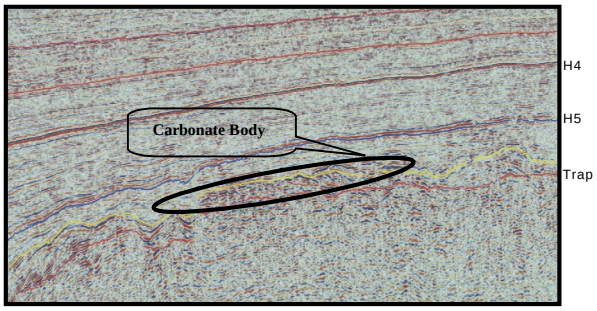

Fig.8. Paleocene carbonate over basinal high in Tapti area

Fractured Basalt Play

Fractured basement i.e. basalts may form unconventional hydrocarbon play in Heera-Panna-Bassein and Tapti-Daman blocks of Eastern Homocline area, which forms the eastern rising flanks of Central Graben and Surat depression. Hydrocarbon accumulation is already observed within fractured basalt in few drilled wells in the southern arm of eastern rising flank of Central graben. In the contiguous part of Cambay Basin hydrocarbon occurrence is also known in the same plays. In view of this, the vast stretch of Eastern Homocline is would be encouraging for exploration of fractured basalt.

Basin Centered Gas Accumulation

Possible Basin Centered Gas accumulation is another important and challenging deep exploration plays in the basinal lows of Bombay offshore basin. Basin centered gas accumulations (BCGA) are large basin wide synclinal accumulations of gas in deep abnormally pressured sequences. The gas accumulations are found typically low permeability reservoirs encased within mature source rocks (Law, 2002). These accumulations are unconventional since entrapment is not gravity controlled and downdip gas water contacts are not seen. The hydrocarbon accumulations are thought to be the product of highly mature source rock low permeability reservoirs subjected to a high pressure and high thermal regime. Buoyancy effects are not supposed to be a factor in these unconventional plays.

Bombay offshore basin has major basinal lows having wide area and sediment thickness of about 5000m. Basin Centered Gas accumulations are envisaged within the major lows viz. Daman low and Central graben, which are yet to be established. The Paleocene-Early Eocene sequence is well known to be effective and matured source rock, which have generated and expelled substantial quantities of hydrocarbons in basinal depocentres. The sequence is also known to be overpressured in the basinal lows and flanks. The maximum overpressures are observed towards the central part of Purna and Daman lows.

Tapti-Daman block has got the geological potential favorable for basin centered gas accumulations in the older Panna sequence in the deeper parts of the basinal lows. Recent drilling in one of the deep well in the northern rising flank of Daman low has encountered thick section of tight sandstones and shale around 4000m. The sands are tight with average porosity of 6-8% and saturated with gas. Some of the intervals have yielded non commercial flow of gas at low flowing pressures. In the southern part of Daman low thin high pressured sands were encountered within this sequence with continuous gas shows. However, these could not be tested due to technical complications. In the Navsari low to the north-east, gas shows were recorded within sequence both during testing and drilling form the wells drilled in the flank of the low. These sands were moderately high pressured. It is thought that the pore pressure system would be high in the main low part.

Similar situation is also envisaged in the Central graben for occurrence of basin centered gas. Continuous gas shows were observed during drilling in few wells in the flanks. Thus, the existence of BCGA system in these lows particularly the Daman low and Central graben is quite a possibility and focused exploration approach has to be adopted including data acquisition and drilling of R&D locations.

Explorations Challenges and Strategy

The major challenges in exploration of deeper plays include integrated geological modelling of the deeper plays, seismic imaging and mapping of the thin and discontinuous sands, combating high pore pressure during drilling and exploration of unconventional plays like Basin Centered Gas Accumulations (BCGA).

Integrated geological modelling of the deeper plays within Panna sequence on a basinal scale as well block wise is one of the challenging areas for exploration. Understanding of configuration and distribution of granitic/basaltic basement and sediment dispersal pattern for Panna Clastics through integrated study of available geoscientific data is warranted at this stage. Evolving integrated geological models for the Paleocene-Early Eocene sequence for different blocks would be relevant for exploration of clastic plays within Panna Formation in view of the varied litho- facies, thickness and sedimentation history. Depositional models of the sands, geometry of sand bodies and entrapment conditions are to be firmed up.

Occurrence of high pore pressure and high temperature (HPHT) in the deeper plays causes severe problems in well data acquisition including well logging, MDT, well testing and completion. The southern and central parts of Tapti-Daman block, Central graben in Heera-Panna- Bassein block are characterized by high pore pressure and high temperature. Overpressure up to 18 ppg MWE have been encountered in number of wells. Combating high pore pressure during drilling often leads to pre-mature well completion and inability to explore for the principal exploration plays. Exploration of unconventional plays like Fractured basalt along Eastern Homocline and Basin Centered Gas Accumulations within the major lows viz. Daman low and Central graben would be highly challenging, which are yet to be established.

New technologies for imaging deeper plays and characterizing the facies and porosity variation may be inducted. Modern technologies for well data acquisition including LWD (Logging While Drilling), NMR, MDT, FMI and ECS etc are very essential for evaluation of deeper plays. Sound well completion practices for handling high pressure and high temperature (HPHT) problems, mud loss problems are to be followed by designing suitable well design. New technologies for well completion with 'Expandable Casing' and 'Casing While Drilling' may also be adopted for smooth completion of deep wells.

Conclusions

The deeper plays viz. Paleocene-Early Eocene clastic play, Paleocene- Early Eocene carbonate play; Fractured basalt play and possible Basin Centered Gas Accumulations (BCGA) in the basinal lows need to be focused for hydrocarbon exploration in Bombay Offshore Basin.

The Paleocene-Early Eocene sequence is divisible in to three major units from bottom to top: viz. - Lower, Middle and Upper units, based on litho-association. The Lower unit comprising Trap Wacke/ Trap wash and alternations of siltstone/ sandstone and shale is inferred to be deposited in a fluvial / palludal environment as alluvial fans. The Middle unit consisting of sandstone, siltstones, limestones, carbonaceous shale and coal has been deposited in a coastal swampy- marginal marine environment. The upper unit comprising mainly shale is associated with a marine transgression. The Lower unit is mainly confined to the pronounced depressions with depocentre. The Middle and Upper units are more widespread compared to the lower unit.

The hydrocarbon accumulations within the Paleocene-Early Eocene sequence are mainly strati-structural plays governed both by the development of reservoir facies, its continuity and the structural configuration. The rising flanks of Daman low and Navsari low in Tapti- Daman block, Diu depression in both in Panna-Bassein and Bombay high-DCS blocks and rising flanks of Central graben would be encouraging for the deeper plays. The southern part of Bombay high-DCS block having intertounging stratigraphic plays in the clastics and carbonates within the Paleocene-Early Eocene section would also be a promising area for exploration of deeper plays. The prospective areas for exploration of deeper plays are shown in fig.9.

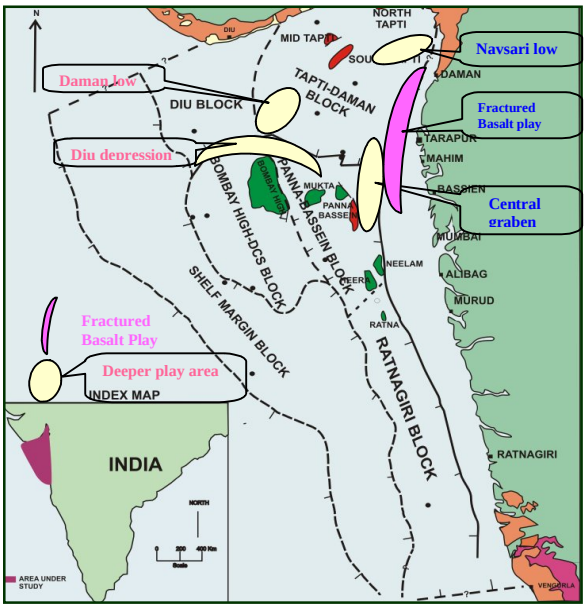

Fig. 9. Map showing prospective areas for deeper plays

Paleocene carbonates over the basement highs needs to be pursued for further exploration. Concerted efforts for exploration of unconventional plays like Fractured basalt and Basin Centered Gas Accumulations (BCGA) are to be initiated on priority. Daman low may be taken in priority for establishing BCGA beside Central graben.

The major challenges in exploration of deeper plays include geological modelling of the deeper plays, seismic imaging and mapping of the thin and discontinuous sands, combating high pore pressure during drilling and establishing the unconventional plays like Basin Centered Gas Accumulations (BCGA).

Integrated geological modelling of Paleocene-Early Eocene sequence on a basinal scale as well block wise has to be carried out for a better understanding. Intensive adoption of new technologies including Q Marine for imaging deeper plays, sound well completion technology for handling HPHT related problems and modern electro-logging suites including LWD (Logging While Drilling), MDT, NMR, FMI and ECS etc for evaluation of deeper plays has to be hastened for exploration and exploitation of deeper plays.

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