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Development of a Super Giant, ACG Field, Offshore Azerbaijan: An Overview

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Introduction

The ACG Oil Field is situated to the SE of Baku, offshore Azerbaijan in water depths of between 60m and 280m. The ACG structure is comprised of three linked culminations, which are, from west to east Shallow Water Gunashli (not in PSA), Deep Water Gunashli, Chirag and Azeri. The AIOC (Azerbaijan International Oil Company) consortium, made of 10 different oil companies, from 6 different countries agreed the Production Sharing Agreement (PSA) terms with Azerbaijan in December, 1994. The PSA term is for 30 years at which time the field will revert back to Azerbaijan. BP operates the field on behalf of the shareholders which include the following companies: BP 34.14%, UNOCAL 10.28%, SOCAR 10%, LUKOIL 10%, Statoil 8.56%, ExxonMobil 8%, TPAO 6.75%, Devon 5.63%, Itochu 3.92% and Delta Hess 2.72%.

The ACG structure covers approximately 135 square kilometres and has had a two phases of appraisal. The State Oil Company of Azerbaijan Republic (SOCAR) drilled 8 appraisal wells from 1982 – 1991 within the PSA boundary. AIOC has drilled a total of 5 appraisal wells and 4 sidetracks to date. In addition, the Chirag sector of the field has 15 development wells and has been on production since 1997. Chirag is currently producing ~ 125,000 bopd.

Figure 1 – Location Map

1994: AIOC signs PSA Agreement

BP	34.14%
Unocal	10.28%
SOCAR	10.00%
LUKoil	10.00%
ExxonMobil	8.00%
Statoil	8.56%
TPAO	6.75%
Devon	5.63%
Itochu	3.92%
Delta Hess	2.72%

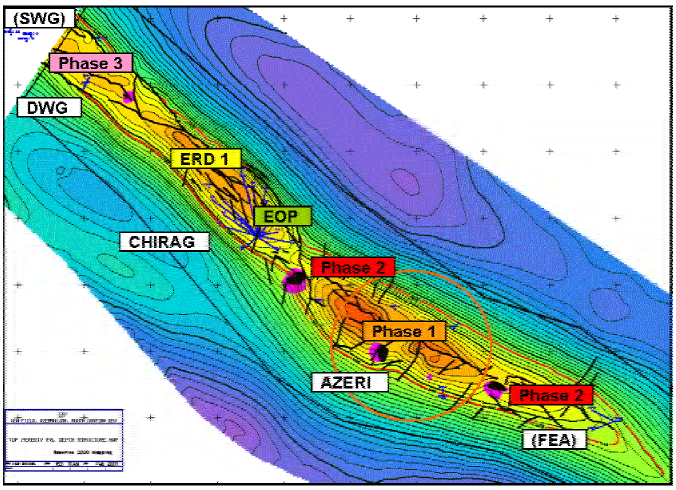
1997: Chirag First Oil
2005: Azeri First Oil
2024: PSA expires

Reservoir Description

The trap, which forms the giant ACG Oil Field is a NW-SE trending, steeply dipping thrusted anticline. Within structural closure there are a number of crestal faults oriented along strike as well as mud volcanoes of varying size which complicate the otherwise straight forward structural geometry. Hydrocarbons are found within several different stratigraphic intervals within the Pliocene, the most important reservoirs occur in the Pereriv and overlying Balakhany Formations. The extensive oil column that characterises the field is the result of high structural relief combined with excellent top and lateral seals, for example, 900m on the north flank of Azeri and 580m on the south of Chirag. Differing pressure regimes combined with effective seals may be responsible for the greater than 300 m north-south changes in oil contact(s). At the main Pereriv reservoir level, the ACG Field is 50km in length and 5km in width.

Hydrocarbons are thought to have been sourced and migrated from Late Miocene to Early Pliocene aged Maykop lacustrine shales buried in the deep and rapidly subsiding South Caspian basin to the south of ACG. The ACG structure formed in the Late Pliocene in response to compression associated with the formation of the Alpine/Himalayan mountain belts to the south. Release of overpressure from deeply buried shales exploited lines of weakness associated with the inversion and faulting forming the numerous mud volcanoes some of which are still active today.

Figure 2 – ACG Structure with Development Phases

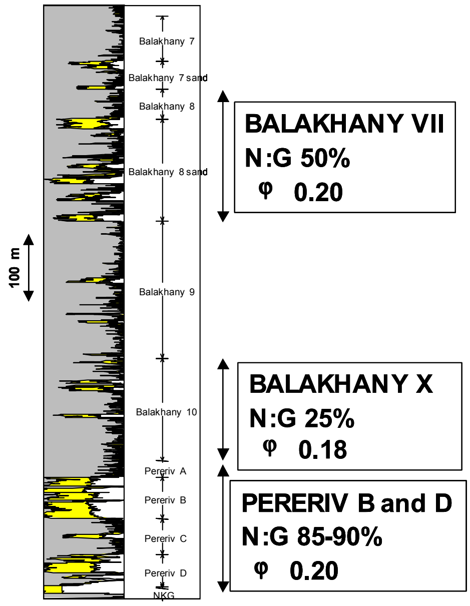


Stratigraphy and Reservoir Development

The Pereriv Formation forms the main ACG reservoir and is subdivided into 5 units, A to E. The Pereriv B and D sands are the most significant producing intervals. Secondary reservoirs are found both beneath (NKP, PK, Kalinsk) and above (Balakhany, Sabunchi, Surakhany) the Pereriv. The Balakhany is subdivided from V through X with the Balakhany VIII and X the most significant.

The main ACG reservoirs were deposited in a range of environments associated with a large river-dominated lacustrine delta. A dominant palaeo-flow direction of NNW to SSE has been interpreted (160°). Pereriv reservoirs are laterally extensive and vary little in thickness reflecting sand-rich depositional systems and low relief palaeo-topography. Laterally persistent lacustrine shales separate the Pereriv into five separate reservoirs and records the interplay between lacustrine expansion across a low-relief floodplain and fluvial deposition. The Pereriv and Balakhany sediments record sand-prone and shale-prone stacking patterns associated with alternation between more proximal and distal environments of deposition. Delta plain facies are more sand-rich and have better connectivity than delta front facies. The cyclicity records delta advance and retreat related to climate changes in the palaeo-Volga system producing variations in lake level.

Figure 3 – Stratigraphy



Reservoir quality is controlled by facies (ductile content and grain size) and maximum depth of burial. Although grain sizes are dominantly fine-grained, the overall reservoir quality is good to excellent due to excellent sorting (absence of interpartical shale) and the absence of pervasive authigenic cements in the main reservoirs. Average net to gross ranges for the Pereriv B and D are 0.80 to 0.95 while other reservoirs in the Pereriv and Balakhany are more variable averaging 0.12 to 0.50. Average porosity ranges for the Pereriv B and D and the Balakhany VII and VIII are 0.19 to 0.22 while other reservoirs in the Pereriv and Balakhany range from 0.16 to 0.18. Average permeabilities for the Pereriv B range from 50mD - 500mD in the Chirag and Azeri Fields. There is a decrease in permeability from West Chirag to East Chirag towards the large field-bounding mud volcano. The Pereriv D reservoir has slightly lower average permeabilities than the overlying Pereriv B.

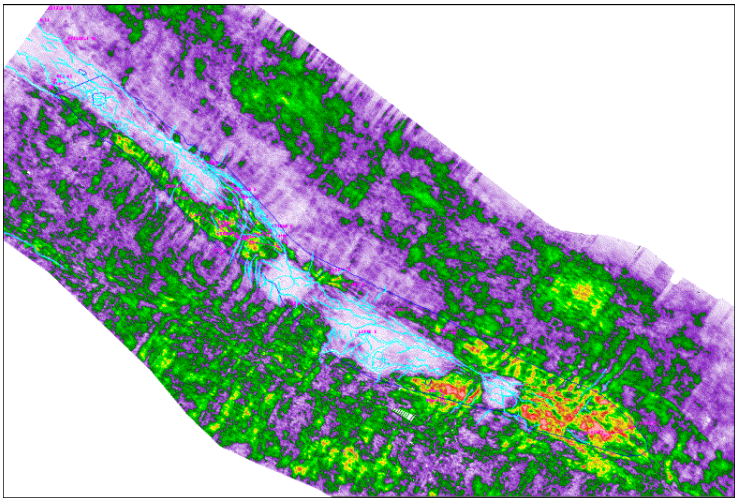
Fluids and distribution

Ten appraisal wells have been tested in ACG but only three have reasonable pressure build-up data. These three tests cover the Balakhany X, Pereriv B and Pereriv D reservoirs. The Chirag platform wells have been production or injection tested.

Fluid samples are available from Chirag platform wells, but elsewhere on the ACG structure representative fluid properties have only been taken in a few wells from the Balakhany X, Pereriv B and Pereriv D intervals. ACG appraisal wells GCA-1 and GCA-2 have DST data that were used to derive GOR's of between 700 scf/bbl and 900 for the Balakhany X and Pereriv reservoirs. Crude oils from these reservoirs have moderate API's, varying from 32° to 36° that generally increase from west to east, low sulphur, and low to moderate wax content (up to 8.5%wt in Chirag, 16%wt in Azeri). Shallower reservoirs in Chirag, for example the Balakhany VIII and VII, have suffered biodegradation leading to a reduction in API to 25° to 26° and have higher viscosities, higher sulphur and lower wax than the underlying reservoir intervals. Significant concentrations of H_2S have been found in the Pereriv D and E in the Azeri Field in association with sulphate reduction close to oil-water contacts.

Fluid contacts are defined partially by well data and partially on 3D seismic. Contacts vary between stratigraphic intervals and between fault-bounded segments. Mud volcanoes that puncture the crest of the structure also provide vertical and lateral barriers. Upper Balakhany reservoirs are generally gas-filled. From the Balakhany VI through the Pereriv, reservoirs are oil-filled and some of the Balakhany reservoirs have extensive gas caps. Aquifers extending down-flank the Chirag Pereriv hydrocarbon column have provided excellent pressure support.

Figure 4 – Pereriv B Amplitude – Hydrocarbon Indicator



Resource / Reserves Base

Recent studies estimate the total STOIIP between 13 – 13.5 billion barrels of oil. Full field reserve estimates, excluding Shallow Water Gunashli are between 4 and 5 billion barrels of oil recoverable within the PSA timeframe. Of the four most significant reservoir intervals, the Pereriv B contains 40%, Pereriv D 21%, Balakhany X 14% and Balakhany VIII 13% of the recoverable reserves. The API gravity of the bulk of the recoverable oil ranges from 32-36 and is low in sulphur and asphaltenes.

Database

Deepwater Gunashli, Chirag and Azeri have 100% 3D seismic data coverage from a single survey acquired in 1995. The data has been reprocessed (pre-stack depth migrated) over Chirag and more recently Azeri to address serious image quality problems. In the areas of 3D coverage it has been determined that steep dips, faulting, mud volcanoes and gas chimneys are the main causes of the observed degradation in seismic data quality. Shallow Water Gunashli has a multi-vintage variable quality 2D grid. The structural interpretation in this area is based on integration of the numerous wells drilled to date and the 2D seismic.

The 5 AIOC appraisal wells, drilled from 1996 to 2000 are distributed across the ACG structure and provide, for the most part, complete modern log suites through the main reservoir zones. Fifteen development wells have been drilled on Chirag from 1997 to present and also have modern logs. Earlier SOCAR exploration and appraisal wells drilled from 1982 to 1991 have less data. Core coverage is generally concentrated in the Pereriv and is sparse elsewhere in the section. Well spacings are highly variable – from <0.5km in the producing areas to 9-10km from east to central Azeri and from Chirag to Deep Water Gunashli.

Existing Development

Current production in ACG is from the Chirag field, which is estimated to contain greater than 700 MMstb of reserves to be produced to the end of the PSA period from 24 slots, with an expectation that most wells will be sidetracked at least once. Cumulative production to date is some 120 MMstb.

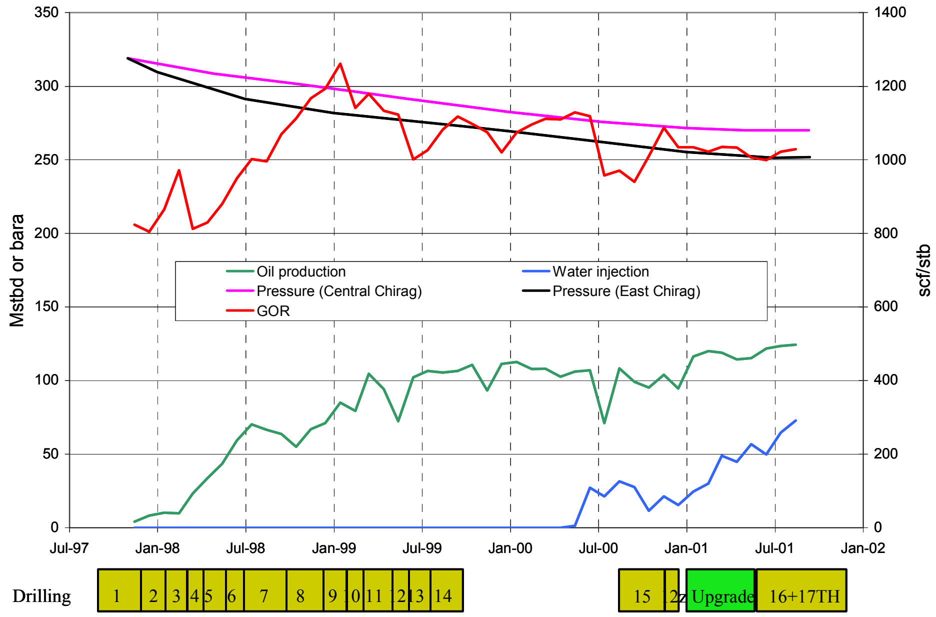
Production commenced in late 1997 and is presently at a level of around 125 Mb/d from 12 producers. The field is being developed under waterflood, which commenced in mid 2000, and three wells are on injection at a combined rate of 75 Mb/d. Reservoir pressure has fallen by some 1000 psi from initial conditions and is now approximately 500 psi below the bubble point. The field GOR is currently around 1050 scf/stb, some 35 % above solution GOR (Figure 5). The onset of water injection has caused reservoir pressure to level off and it is expected that 100 % voidage will be achieved during 2002.

Sand production is a challenge in Chirag, triggered by water crossflow in the injectors and water production in the single producer to have cut water. Open hole gravel packs are the primary means of sand control with expandable sand screen technology planned to be tested in 2002.

RFT pressure data indicates that all parts of the reservoir so far contacted have experienced some level of depletion – ie there are no fully sealing compartments. There is evidence, however that pressure differences exist between groups of wells , suggesting the presence of extensive baffles within the reservoir.

The initial development plan was based on accessing reserves within a drilling radius of about 4km. In early 2000, following evidence that high well rates (>15Mb/d) were achievable, and that reservoir conformance was good, the decision was taken to extend the development area of Chirag to 6.5 km by upgrade the drilling rig for extended reach duty, and to upgrade the production facilities capacity to 140 Mb/d. Future plans for Chirag include the possibility of further debottlenecking of the production facilities.

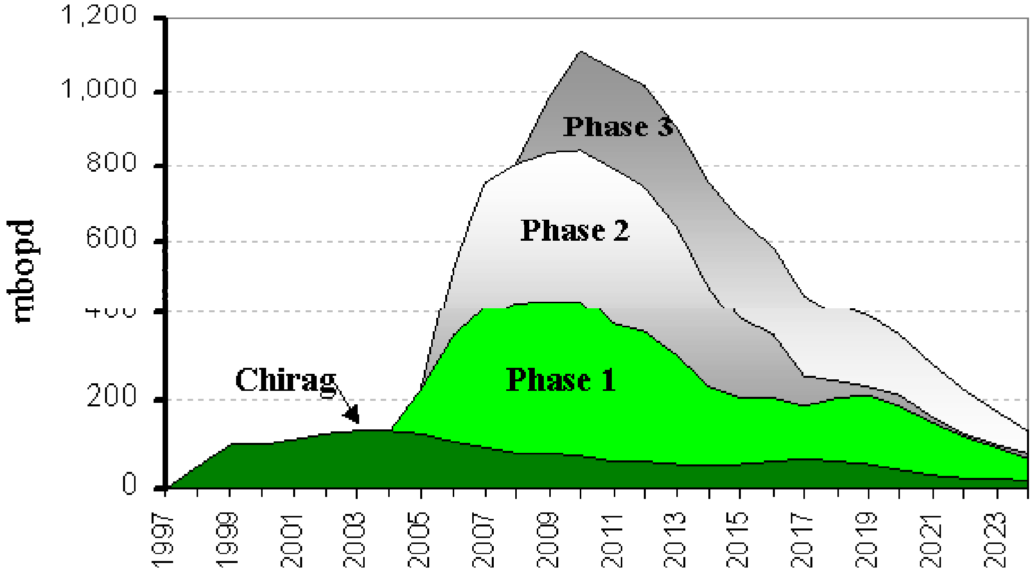
Figure 5 - Chirag Production/Injection and reservoir pressure



Future Development

The full field development for ACG is based on three Phases of development covering the undeveloped segments of the structure - Azeri and Deepwater Gunashli. Approximate development timings and profiles are indicated below in Figure 6. Locations on the development phases are illustrated in Figure 2. In the sequencing of the development, priority is given to the Azeri segment, which contains a higher reserve density and a lower level of pressure depletion than the Deepwater Gunashli segment. Peak production is expected to exceed 1 million b/d by 2010.

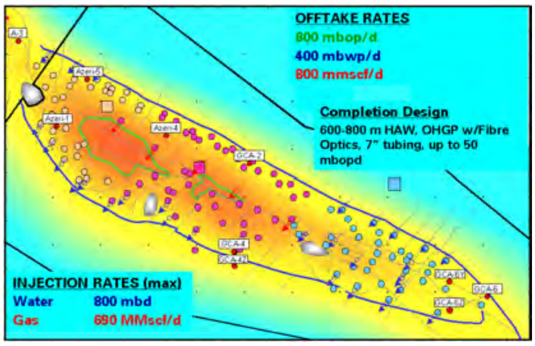
Figure 6 – ACG Production by development phase



Azeri Segment Development

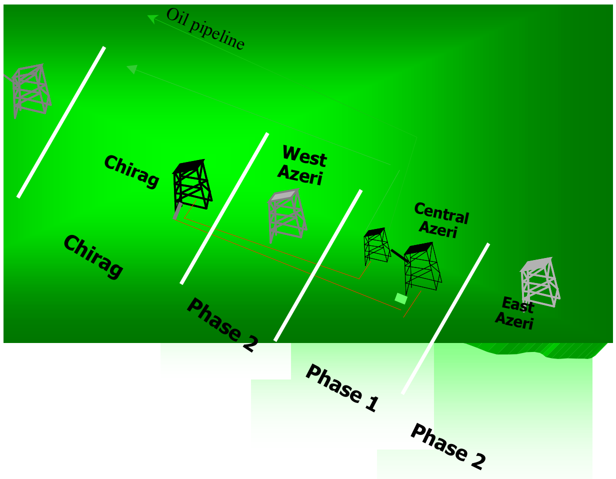
Phases 1 and 2 are focused on the development of the Azeri portion of the field. The development of the Azeri segment is based on the application of gasflood on the steeply dipping North Flank of the structure, with waterflood elsewhere. Planned injection rates are currently being finalized are are anticipated to be near 800 mbwpd and close to 1000 mmscf/d. The provision of central facilities for secondary recovery will offer considerable flexibility in the deployment of pressure support. Wells will be designed for high initial well rates (50 Mb/d) with openhole gravel packs or expandable sand screens being the primary means of sand control.

Figure 7 – Azeri Sector Development



RESERVES AND PRODUCTION

- STOIIP (mean) ~8200 mmbbls
- Reserves (end PSA) ~3000 mmbbls
- First oil 2005
- Plateau oil 800 mbd
- End PSA 2024



DEVELOPMENT CONCEPT

- Four platforms
- Two 30" oil pipelines
- One 24" gas pipeline
- Gas and water injection
- 136 well slots
- 142 sidetracks

Key Technologies

- As already mentioned, **expandable sand screens (ESS)** will be trialed in Chirag , probably in 2002. This technology will allow sand control coupled with conformance, important for the development of the multi-layered Pereriv reservoir.

- **Fibre optic technology** will also be applied to allow surface monitoring of downhole pressure and temperature along the wellbore both in producers and injectors. This will prove important for effective reservoir management.

- **4 component ocean bottom seismic** technology will allow imaging of the reservoir beneath areas affected by shallow gas. This technology has been piloted at a reduced scale in Azeri and will be applied in full in Azeri in 2002. Significant benefits to well placement and reservoir management are expected.

Acknowledgements

We would like to highlight the valuable contributions of Sue Love (Exxon Mobil) and Ian Roberts (BP).