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Depositional models and reservoir architecture of the Siluro-Devonian series in outcrops and subsurface of Illizi basin (Algeria)

Messaouda Henniche[a1], Rémi Eschard[b], Jean Noël Proust[c], Aïcha Hamel[a2], Florentin Paris[c]

[a1] : Sonatrach-Centre de Recherches et de Développement, Avenue du 1er Novembre-Boumerdès-Algérie, 35000, phone 213 24 81 11 23/25, Fax 213 24 81 86 86, e-mail dalila.henniche@libertysurf.fr
[b] : Institut Français du Pétrole, 1 & 4 Avenue de Bois Préau, Rueil Malmaison, Paris, 92852 Cedex, France.
[a2] : Sonatrach-Petroleum Engineering and Development, 8 Chemin du Réservoir, Hydra, Alger, Algérie 16035.
[c] : Géoscience-Rennes 1, CNRS, UMR 6118, Campus de Beaulieu, Bat 15, Avenue du Gal Leclerc, F-35042 Rennes Cedex, France.

The study of the Siluro-Devonian sedimentary cycle from field exposures in the Tassilis des Ajjers, as well as core and log data from drillholes in the Illizi basin, led us to reconstruct the detailed stratigraphic architecture of the stacked sediment bodies from the scale of the cratonic platform (100 kms) to the scale of the oil field and reservoir (10 kms).

I. Facies and depositional environments

The Siluro-Devonian deposits in the western Illizi Basin and in the Tassili des Ajjers are made up of a series of lithofacies that can be grouped into three major lithofacies groups: the Alluvial Plain, the Coastal Plain and the Shallow Marine, each one discussed separately below.

- Alluvial plain lithofacies group: The alluvial plain lithofacies group comprises braided, meandering, and low sinuosity fluvial deposits and also a flood plain lithofacies association.

On field exposures, the braided fluvial deposits lie at the base of the major sandstones units called “Barre Inférieure” and “Barre Moyenne” Formations. They are dated respectively from Upper Silurian (Ludlow?) and Lower Devonian (Lochkovian?). The braided fluvial deposits are made up of coarse-grained sandstone in fluvial channels and bars giving rise laterally to minor silty shales in the flood plain. These fluvial systems are interpreted as braided-delta typically deposited on large pre-vegetated cratonic platforms with a high sediment flux.

The low sinuosity fluvial systems were observed in the “Barre Moyenne” and “Barre Supérieure” Formations. They are dated from the Lower Devonian and possibly respectively Lochkovian and Praguian. They are made up of four lithofacies corresponding to medium to coarse-grained sandstones interpreted as channels and bars déposits, and fine-grained sandstones to siltstones interpreted respectively as levee and flood plain deposits. These deposits are well developed either in the proximal and distal parts of the alluvial plain. In the proximal part, they typically exhibit well-developped, m-scale, 2D, confluence longitudinal bars which pass basinward, in the distal part, to tidally-reworked, mouth bar deposits.

The meandering systems were observed in the “Barre Supérieure” Formation. They are dated from the Lower Devonian (Praguian?). They are made up of five lithofacies corresponding to coarse- to medium-grained sandstones interpreted as channels and bars deposits and fine-

grained sandstones to siltstones interpreted as levees, flood plain and plug deposits. From the early Praguian, flood plain deposits exhibit pedogenetic and root traces which could have favored the stabilisation of the rim of fluvial channel and then their meandering.

Flood plain deposits are well developed in the "Trottoirs" Formation. They are dated from the Praguian. Flood plain deposits are composed of four lithofacies coresponding to fine-grained sandstones interpreted as crevasse and levee, and rootled muddy siltstone with occasional lateritic soils.

- Coastal plain lithofacies group: The coastal plain lithofacies group comprises ephemeral lake, estuarine, and tidal flat lithofacies associations.

Ephemeral lake deposits were identified in the "Trottoirs" Formation in the northern part of Illizi Basin. They are dated from Lower Devonian (Praguian). They are made up of two lithofacies corresponding to fine-grained sandstones and silty mudstone interpreted as lacustrine and mouth bar deposits.

Estuarine deposits were observed in the "Barre Inférieure" and "Barre Supérieure" Formation. They are dated from the Upper Silurian (Ludlow?) and Lower Devonian (Praguian?). They are made up of two lithofacies coresponding to medium to fine-grained argilaceous sandstones interpreted as channel and estuarine bars reworked by tidal currents.

Tidal flat deposits were observed in the "Talus à Tigillites" Formation. They are dated from the Upper Silurian (Ludlow?). They are made up of four lithofacies corresponding to fine-grained argilaceous sandstones interpreted as typical tidal flats (mud- to sand-rich) and tidal channels.

- Shallow marine lithofacies group: The shallow marine lithofacies group comprises shoreface and open marine, shelf lithofacies associations.

Shoreface deposits were identified in "Unit M" and "Orsine" Formations. They are dated respectively from Silurian (Landovery?) and Lower Devonian (Emsian). They comprise three lithofacies made up of medium- to fine-grained sandstones organised into low angle clinoforms of large lateral extent. They are interpreted as wave-dominated, lower and upper shoreface deposits locally reworked by storm waves and tidal currents.

Open marine, shelf deposits were identified in the "Silurien argileux" Formation. They are dated from Silurian (Landovery and Wenlock). They are made up of marine shales interpreted as low energy offshore marine deposits.

II. 100 kms-scale stratigraphic architecture: the Illizi basin

The large-scale stratigraphic architecture of the Siluro-Devonian deposits in the Illizi basins is summarized on a 500 km-long cross section drawn from the field exposures, in the south, in the Tassilis les Ajjers, to the subsurface oil fields, in the north, in Tin Fouye area, throught a set of 20 electric logs (fig 1). The cross section was drawn by correlating small scale (genetic) sequences and their stacking patterns observed on the outcrop to the cored and logged drill holes in subsurface. The datum line choosen for correlation is the base of the Givetian shales.

18 small scale (genetic) sequences were identified on outcrop, cores and logs: nine of them in the Silurian deposits, nine of them in the Devonian rocks. These sequences correspond to five sequences end-members recognized respectively in proximal(*SG1, pfp*), mid-(*SG2, pfm*) and distal (*SG3, pfd*) fluvial environments, in shallow marine (*SG4, pmp*) and shelf environments.

The small scale (genetic) sequences are stacked into four medium-scale sequences: SIL1, SIL2 in the Silurian and DEV1, DEV2 in the Devonian. The stacked, medium-scale sequences exhibit a progradational trend (SIL1, SIL2) overlain by a retrogradational systems tract (DEV1, DEV2) which is interpreted as a full depositional cycle. The depositional cycle lies on the Silurian maximum flooding surface and is capped by the Frasnian maximum flooding surface (Fig.1)

III. Stratigraphic architecture on a 10km scale: the Tin Fouye Oil Field

The detailled study of the geometry of the C1 and C2 units of the Tin Fouye oil field shows that these two reservoir units composed together a full medium-scale sequence. The latter comprizes four small-scale (genetic) units (*SG2, pfm*) that constitute the infilling of an incised fluvial valley.

The lowermost small-scale sequence wedges out laterally. It is made up of fluvial deposits giving rise vertically to lacustrine and tidal deposits. The second and third sequences are composed of fluvial deposits to the south passing upward and northward respectively to lacustrine an flood plain deposits. The topmost sequence exhibits flood plain deposits passing upward and northward to lacustrine sediments. The infilling of the paleovalley is interpreted as deposited during a period of relative sealevel rise and still stand.

IV. Conclusions

The analysis of the sedimentary rock architecture in the Illizi Basin from the scale of the epicratonic platform to the scale of the oil field and the reservoir leads to the following conclusions.

1. The laterally continuous, flat, “parallel-layered”, sandstone units, at 100 kms-scale (“Barre Inférieure”, “Barre Moyenne”, “Barre Supérieure” Formations), exhibit small scale heterogeneities at the scale of the oil field with incised fluvial valley and lacustrine/flood plain interlayerings (i.e. “Barre Moyenne” Formation).
2. The heterogenities in the sandstone and shales units correspond to small scale (genetic) sequences stacked into medium-scale sequences that build up a full depositional cycle at the large scale of the epicratonic platform.
3. The sequences can be correlated along very broad distances onto the platform and could constitute very interesting guidelines for exploration and occurrence of oil reservoirs.
4. We believe the nature and the distribution of the sediment into the depositional sequences in the Illizi Basin best explained either:
    a. by relative sea-level change forced (i) by the evolution of the climate from subpolar in the Silurian, to warm-temperate in the Devonian and (ii) by the southward tectonic tilting of the platform by the early Devonian;
    b. and from the Praguian, by the development in the leveed fluvial channels of the first rooted vegetation. This is probably followed by the increased meandering of the flood plain.