Oil Geochemical Characterization in the Central Part of the Llanos Basin, Colombia*

Alexis Medina[1] and Jörg O.W.Grimmer[1]

Search and Discovery Article #11068 (2018)**
Posted April 23, 2018

*Adapted from extended abstract based on oral presentation give at the 13th Middle East Geosciences Conference and Exhibition, Manama, Bahrain, March 5-8, 2018

[1]CEPSA, E&P S.A., Madrid, Spain (jorg.grimmer@cepsa.com)

Abstract

This work presents the oil geochemical characterization of reservoir oil samples present in the central part of the Llanos Basin in Colombia (foreland). Analyses of API, metals (V, Ni and S), isotopes (saturated and aromatic), SARA, gas chromatography (GC) for the whole oil and gas chromatography-mass spectrometry (GC-MS) for saturated and aromatic fractions were applied to the oil samples in order to estimate their origin and the biodegradation that affected them. Based on the integration of the obtained results, four different hydrocarbon families have been defined, based on star diagrams. This supports assumptions about the history of oil migration in the basin. The results indicate that at least two migration pulses of different ages affected the area. It is likely to assume an oil mixing process with high level of maturity dissimilarity in the same reservoir, where a strong biodegradation process has been effective.

Introduction

The Llanos basin is one of the most prolific and largest sedimentary basins in Colombia (Cooper, 1995). Figure 1 shows the study area. Several sequences led to the development of the basin. The most important sequence took place during early Cretaceous and was dominated by shallow marine sedimentation, which produced excellent Cretaceous source rock known as the Gachetá Formation. Recent studies indicate source rock potential in Cenozoic units, like the Mirador and Carbonera formation (Navarro et al., 2016). These younger units are deposited in a terrestrial setting. Reservoir beds are mainly encountered in sandstones of Cretaceous age (Une, Gachetá, Guadalupe Formations) or Paleogene age (Mirador and Carbonera Formations). Twenty-one oil samples from fifteen wells have been analysed and this abstract focuses on their biomarker content using GC-MS.

Results

Four oil families can be identified. Family 1 has 21-30ºAPI without any indication of biodegradation. This family has a high Pr/Ph and moderate Ni/V ratio, indicative for a marine and deltaic environment. The biodegradation is low (no 25-norhopane/hopane and no “hump” in the GC). It mainly charged Paleogene reservoirs such as Oligocene-C7 and Mirador formations. The presence of oleananes in this oil type may support a Paleogene oil source (Moldowan, 1994). The biomarkers indicate marine deltaic origin with some terrestrial input (see Figure 2 and Garcia Mayoral et al., 2015).

Family 2 contains 25-norhopane/hopane with a ratio up to 1.5, which is an indicator of biodegradation (moderate unresolved complex mixture "hump" in the GC, see Figure 3). The API ranges at 13-20º. The high C27 sterane content may correspond to marine conditions of the source (Peters et al., 2005). The DBT/P ratio is elevated and may indicate a carbonate source. The very low Ni/V support the idea of a marine source environment.

Family 3 has 32-40ºAPI and is very distinct compared to the previous oil families (see Figure 4). The high Pr/Ph is an indicator of a marine source rock. The Ni/V ratio is the highest of the presented oils and indicative for an oxic environment. The unresolved complex mixture "hump" is not present in the GC, which indicates fresh oil without biodegradation. The producing reservoirs are the Gacheta/Une units (Cretaceous in age - see Figure 4). This oil family is comparable with the oil samples described in 1984 by Exxon for well Tocaria-1 (Young and Rinaldi, 1984).

Family 4 has 12-14ºAPI (see Figure 5). High ratio of 25-norhopane/hopane indicate a high level of biodegradation (high unresolved complex mixture "hump" in the GC, see Dzhou, 1999). The presence of n-alkanes in this GC only could be explained because of a mixture with fresh oil containing the light components. Otherwise, the bacteria would have eaten the light components. A possible mix of oil family 2 with family 3 could be assumed, which is supported by the moderate Ni/V ratio. This oil family 4 is mainly present in the Gacheta/Une reservoirs (Cretaceous in age).

Conclusions

Oil family 1 may be generated through an oil mix of different Cretaceous or even Paleogene source rocks. The Pr/Ph and Ni/V ratios support a marine source rock (e.g. Gacheta formation) with a contribution of a potentially Paleogene source, indicated by the presence of oleananes. Analyses of the Paleogene units, especially the Carbonera formation (Navarro et al. 2016) showed very good source rock parameters (TOC up to 55% and HI of 400 mg/g TOC). The oil family 1 has been found mainly in the western part of the study area. In this part of the Llanos the Cretaceous units lie shallower and the migration distance from older to younger Paleogene oil is shorter and therefore more favourable, which facilitates a mixing process.

Oil family 2 is assumed a mixture of a marine oil with the probably biodegraded product of family 1. This is indicated through the clear presence of 25-norhopane/hopane ratio, which is a biomarker that appears only when biodegradation is present. Mainly bacteria favoured through the low temperatures of the sampled reservoirs (below 80 º C) and/or water washing cause the biodegradation. The biodegradation process may have even acted as an additional trapping mechanism based on special hydrodynamic conditions as assumed in the Rubiales oil field (Person et al., 2012). The oil family 2 is produced close to family 1, but further to the southeast.

Oil family 3 can be interpreted as the end member with the highest Ni/V content – the probably pure Cretaceous oil. It is not biodegraded, has the highest API and a high amount of n-alkanes. It is produced in the southwestern part of the Llanos basin and it is highly likely sourced by a marine rock as high Pr/Ph ratios indicate (up to 3%). Some authors (Garcia Bautista et al., 2015) assume a today eroded Turonian source (La Luna and Chipaque formations), but a deeply buried Gacheta source may be a possible source as well.

Family 4 is produced further to the east of family 3. Its GC analysis demonstrates the mixing of a biodegraded product (see the unresolved complex mixture "hump" of the GC) and fresh oil (n-alkane presence). This supports the assumption of a mixture of at least two charges: a former charge that is biodegraded and a latter and fresher charge that is not biodegraded. The former one is the predominant. The latter one has a major terrestrial input.

Up to now the exact process and the location of this mixing is still not clear, either on the way to the reservoir or in the reservoir, but the timeframe is assumed to be in the Pliocene (Garcia Bautista et al., 2015). The impact of biodegradation is nearly everywhere in the Llanos basin visible. This makes a clear oil to source correlation difficult and overprints parameters like Pr/Ph ratios. The described four oil families do partly overlap with other families identified in unpublished reports and in Palmer and Russell (1988). Further investigations will improve the knowledge about the generation and migration history of the oil in the Llanos basin.

Acknowledgments

The authors thank CEPSA for granting permission to publish this paper.

References Cited

Cooper, M.A., F.T. Addison, R. Alvarez, M. Coral, R.H. Graham, A.B. Hayward, S. Howe, J. Martinez, J. Naar, R. Penas, A.J. Pulham, and A. Taborda, 1995, Basin development and tectonic history of the Llanos basin, Eastern cordillera and Middle Magdalena valley, Colombia: AAPG Bulletin, v. 79/10, p. 1421-1442.

Dzhou, L.I., A.G. Holba, J.C. Ramon, J.M. Moldowan, and D. Zinniker, 1999, Application of new diterpane biomarkers to source, biodegradation and mixing effects on Central Llanos Basin oils, Colombia: Organic Geochemistry, v. 30, p. 515-534.

Garcia Bautista, D.F., E. Vaz dos Santos Neto, and H.L. de B. Penteado, 2015, Controls on petroleum composition in the Llanos basin, Colombia: Implications for exploration: AAPG Bulletin, v. 99/8, p. 1503-1535.

Garcia-Mayoral, M.F., R. Rodriguez-Pardo, R., J. Navarro, A. Medina, and J. Grimmer, 2015, Geochemical studies of oils and source rocks from an oil field in Los Llanos Basin, Colombia: EAGE Madrid.

Moldowan, J.M., J. Dahl, B.J. Huizinga, F.J. Fago, L.J. Hickey, T.M. Peakman, D. Winship Taylor, 1994, The Molecular Fossil Record of Oleanane and Its Relation to Angiosperms: Science, v. 265/5513, p. 768-771.

Navarro, J., A. Medina, J. Grimmer, M.F. Garcia-Mayoral, R. Rodriguez-Pardo, and E. Cuñado, 2016, Oil geochemical characterization and source rock analyses in the Caracara Sur field (Llanos basin, Colombia): ACGGP Simposio Bolivariano Bogotá, Colombia.

Palmer, S.E., and J.A. Russell, 1988, The five oil families of the Llanos Basin: III Simposio Bolivariano – Exploración Petrolera en Cuencas Sub-Andinas, Bogotá, Colombia.

Person, M., D. Butler, C.W. Gable, T. Villamil, D. Wavrek, and D. Schelling, 2012, Hydrodynamic stagnation zones: A new play concept in the Llanos Basin, Colombia: AAPG Bulletin, v. 96/1, p. 23-41.

Peters, K.E., C.C. Walters, and J.M. Moldowan, 2005, The Biomarker Guide, volume 1 and 2: 2nd edition, 1155 pages.

Young, W.A., and G.G.L. Rinaldi, 1984, Geochemical study of oil samples from the Llanos Basin, Colombia: Research Application Report.

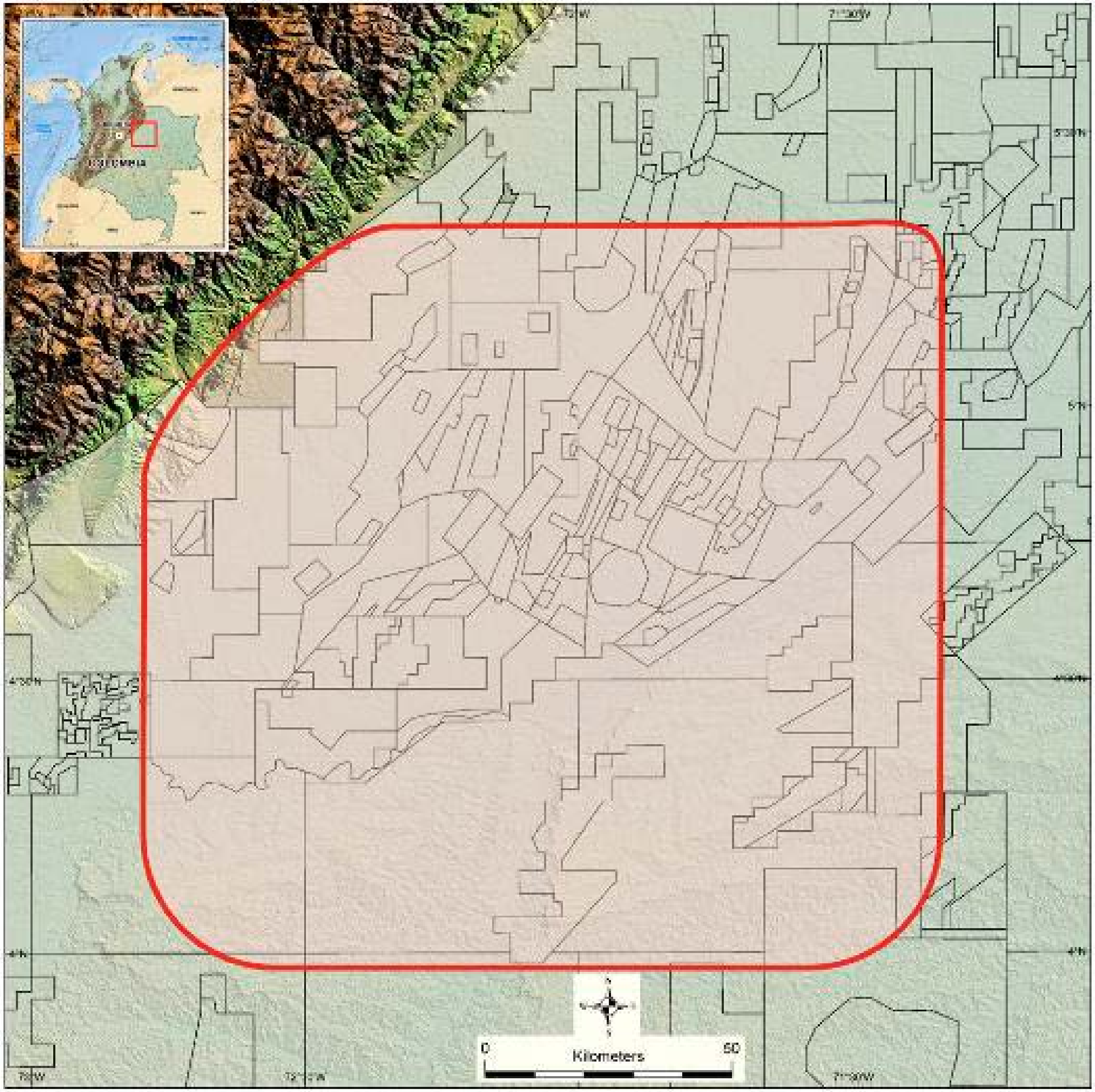

Figure 1. Location map of the studied area (Llanos Basin, Colombia).

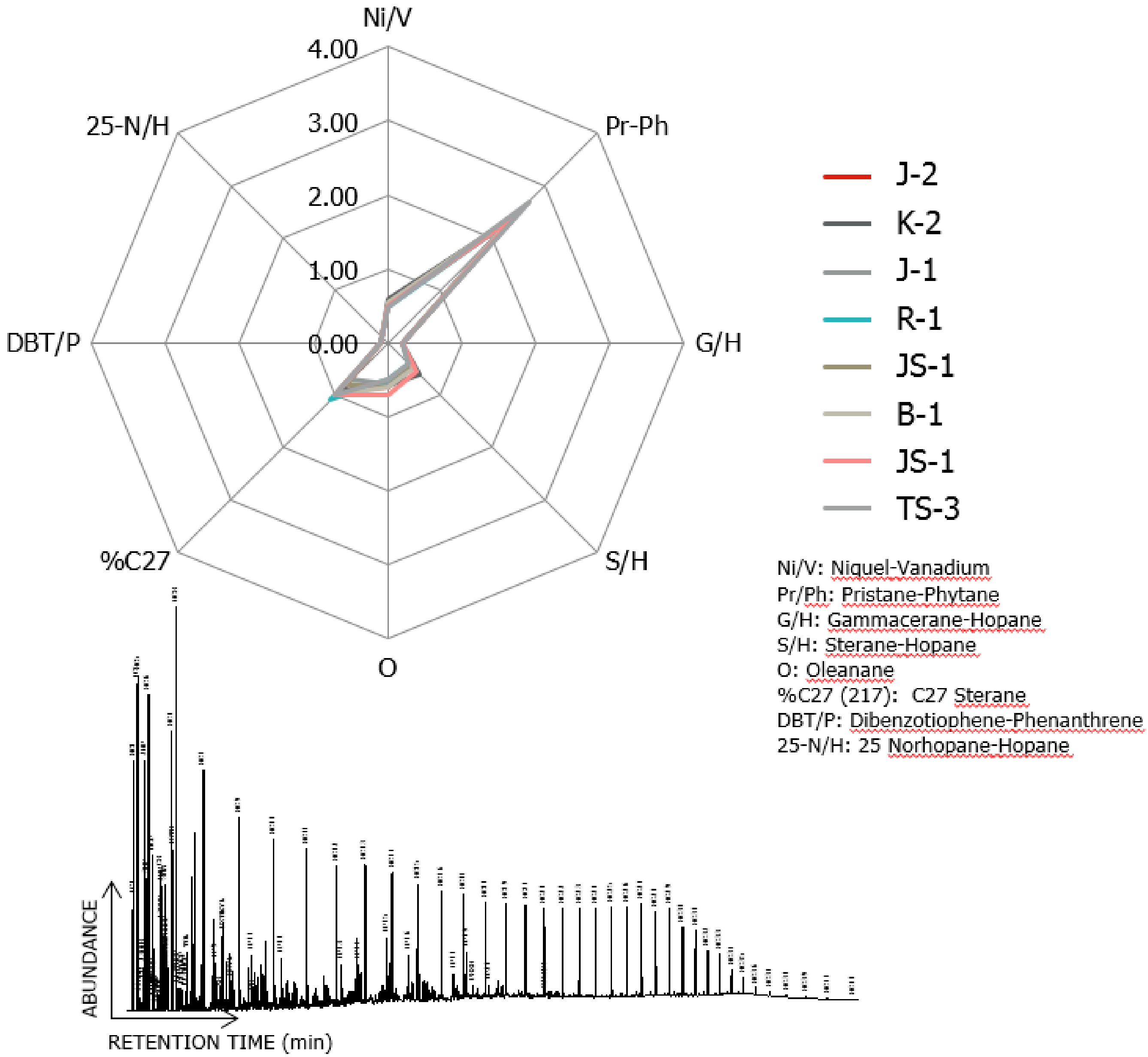

Figure 2. Star diagram with data of eight wells and a characteristic GC for family 1.

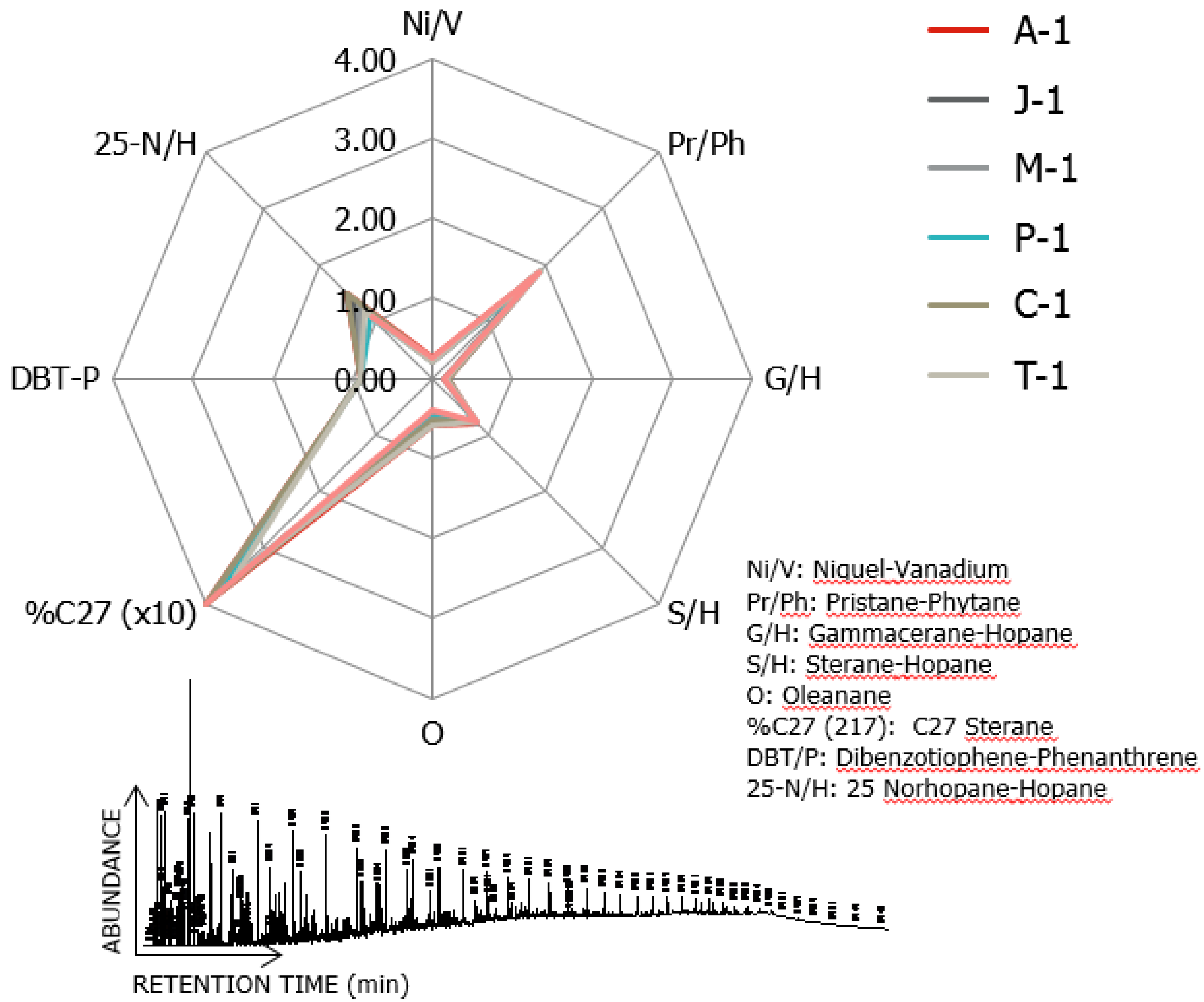

Figure 3. Star diagram with data of six wells and a characteristic GC for family 2.

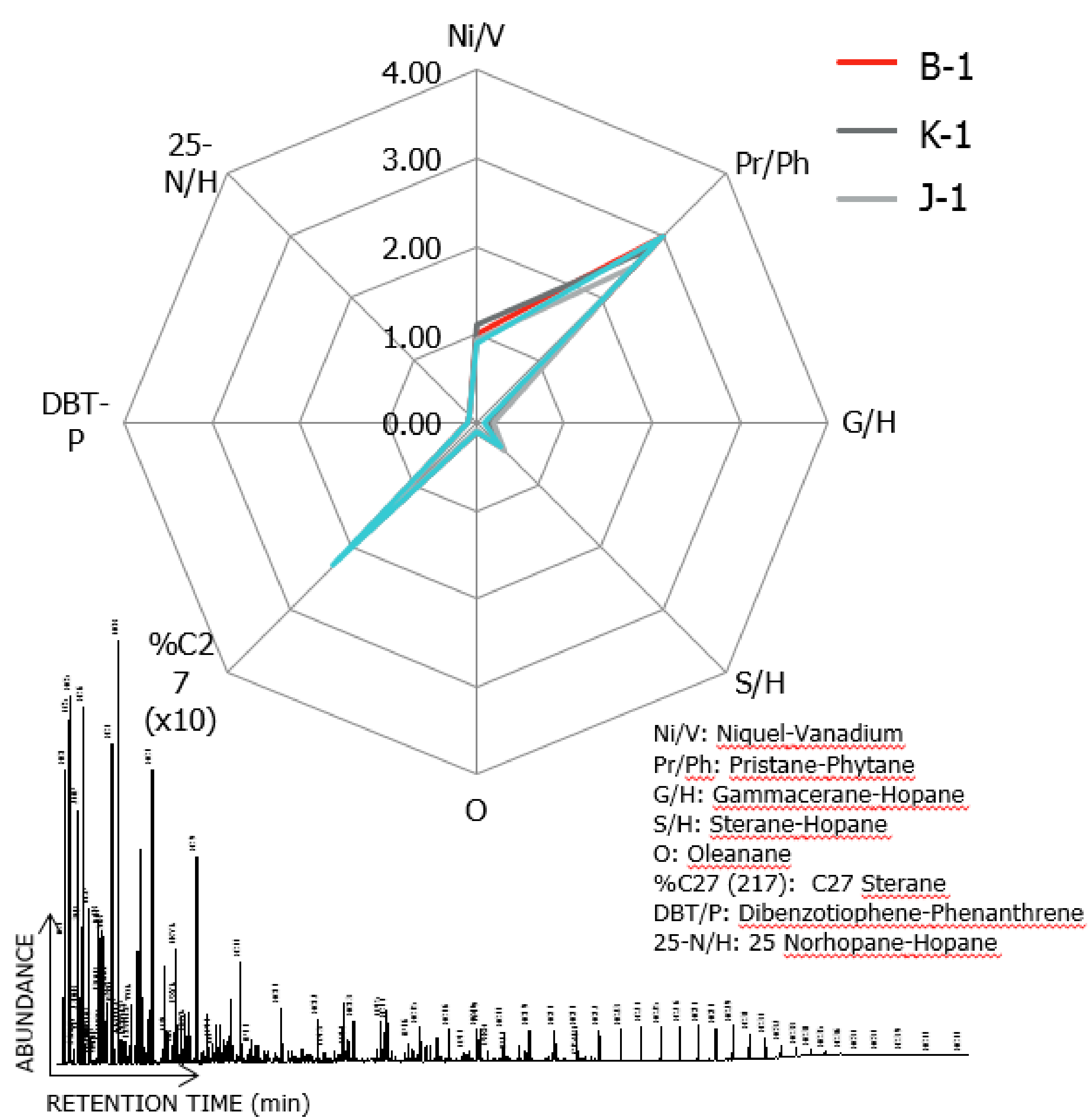

Figure 4. Star diagram with data of three wells and GC for family 3.

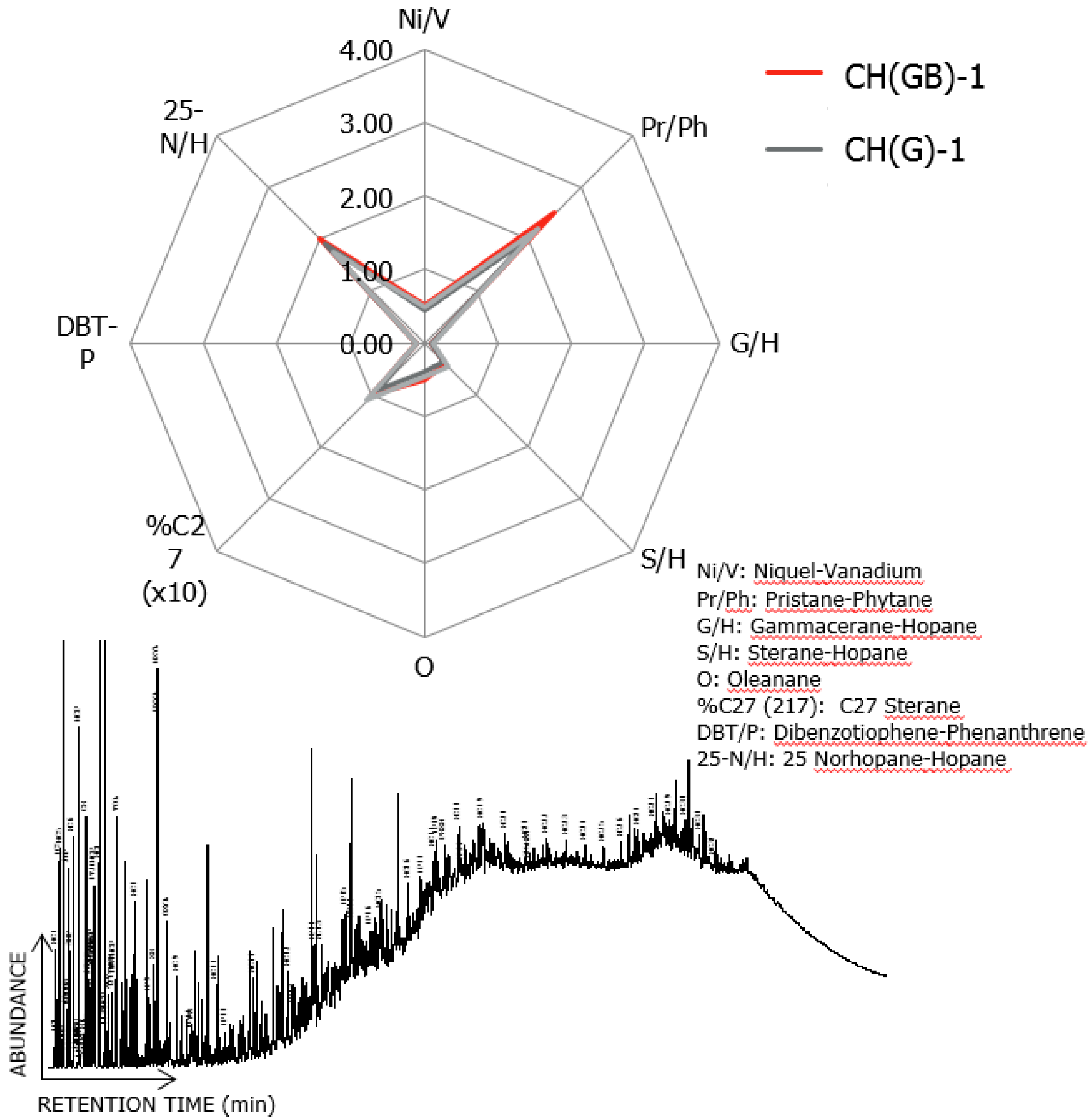

Figure 5. Star diagram with data of two reservoir horizons within one well and GC for family 4.