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AGÊNCIA NACIONAL DE PETRÓLEO, GÁS E BIOCOMBUSTÍVEIS

2023
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ONSHORE
KWANZA BASIN

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Portfolio
OPPORTUNITIES

Block
KON3

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1. Introduction

The portfolio opportunities describe the general characteristics of Block KON 3, presenting the main geological and geophysical aspects from the exploration history, petroleum system, and a series of opportunities identified in the block. This characterization is the result of the survey and framing of existing data, which allowed the seismic interpretation and the elaboration of the geological model by the ANPG/DEX team.

Block KON 3 is in the northeastern part of the Inner Kwanza Basin. With no record of drilled wells, the block was re-evaluated from the correlation with the wells Calomboloca-1 of Block KON 6 and Funda-1, Funda-2, Funda-3, and Funda-4 of Block KON 2. In 2009-2012, 2D seismic surveys were carried out by the Geokinectics Company.

Sonangol conducted recent geological mapping and well geochemistry data survey studies in partnership with Obrangol and Previsão Oil companies from 2010-2015 and 2012- 2015, respectively.

The Kwanza Basin is known for its onshore and offshore exploration history of two significant plays, Pre-salt and Post-salt (Albian and Tertiary). The pre-salt petroleum system comprises the shales from Cuvo Formation as source rock, the sands from Cuvo and carbonates from Toca equivalent Formations are the mains reservoirs, and the seal consists of the massive salt. In the post-salt, the Binga Albian source rock comprises carbonate facies with significant quantities of organic-rich matter. As a reservoir, the carbonates of the same Formation are sealed by the shales from Cabo Ledo Formation. Tertiary trough formation occurred progressively from east to west. The onset of salt-raft tectonism at this time created the accommodation space for the deposition of black-colored organic-rich shales (Cunga Gratidão Fm.) that formed an important source rock in the grabens that feed the sandstone channels from the Quifangondo Formation sealed by the intraformational shale of the same Formation. The trap mechanisms for all plays are structural, stratigraphic, and combined.

Structures with possible accumulation of hydrocarbons in the pre-salt and post-salt were identified. The leads identified from the geological and geophysical data integration present prospective resources estimated from 275 to 2 266 MMBO.

2. **GEOGRAPHIC** Location

Block KON 3, is in the northeastern portion of the Inner Kwanza Basin, in the Catete area. It is bordered by KON 1 to the north, KON 6 and KON 7 to the south, KON 2 to the west, and Precambrian basement to the east and defined by the geographic coordinates parallel 8°40′ 53″ - 8° 58′ 14″ S and meridian 13° 34′ 47″ - 14° 06′ 39″ E, having an extension of approximately 1,385.06 km^2.

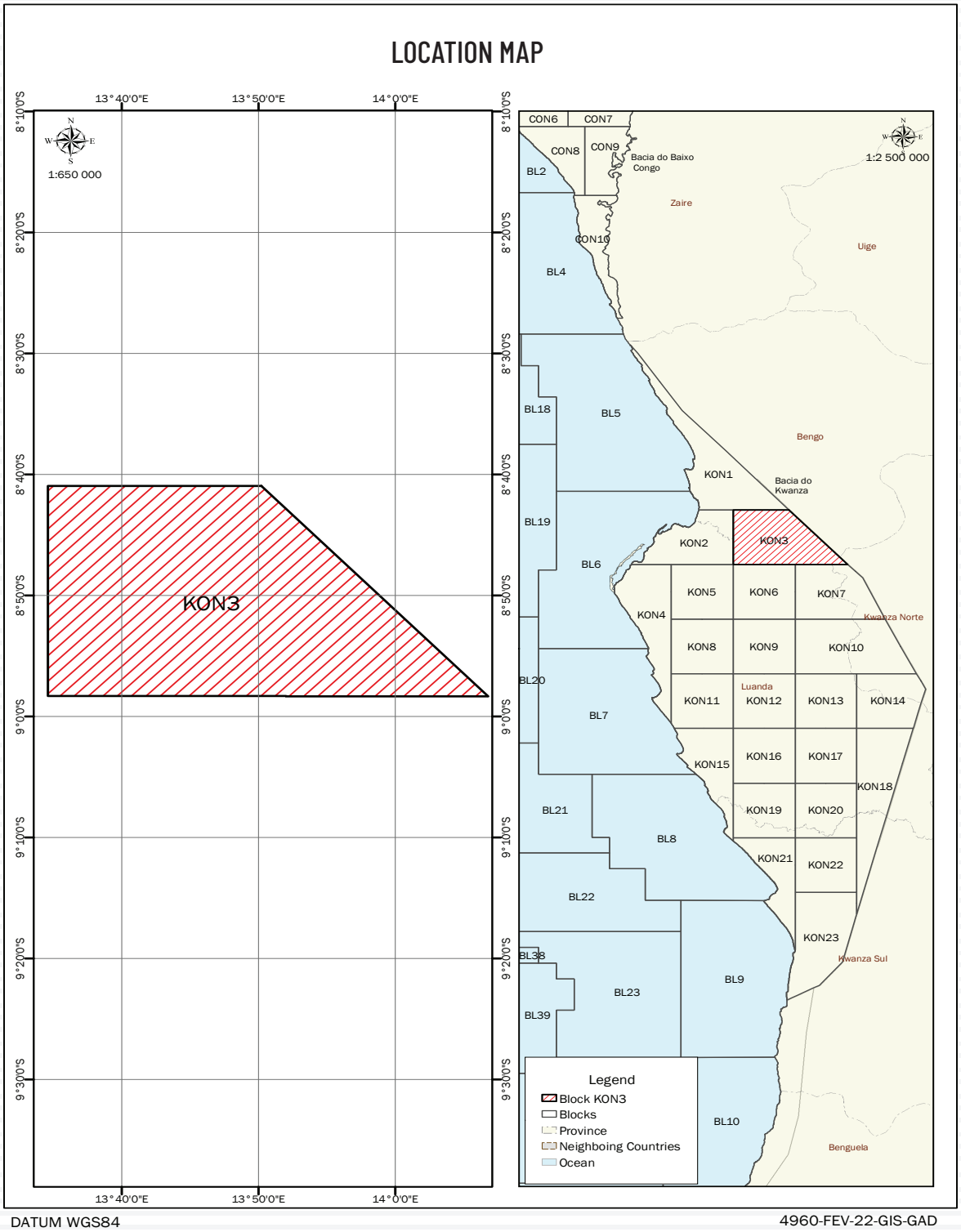

Figure 1: Location map of Block KON3, ANPG 2022

3. **GEOLOGICAL** Setting

The outcrops of Block KON 3 are represented by sediments of Precambrian to recent age, according to the geological chart of the Inner Kwanza Basin (Figure 2). Its sedimentary history is characterized by paleoenvironmental variations between continental, transitional, and marine environments, in which two (2) lithostratigraphic units are evident: Pre-salt and Post-salt play.

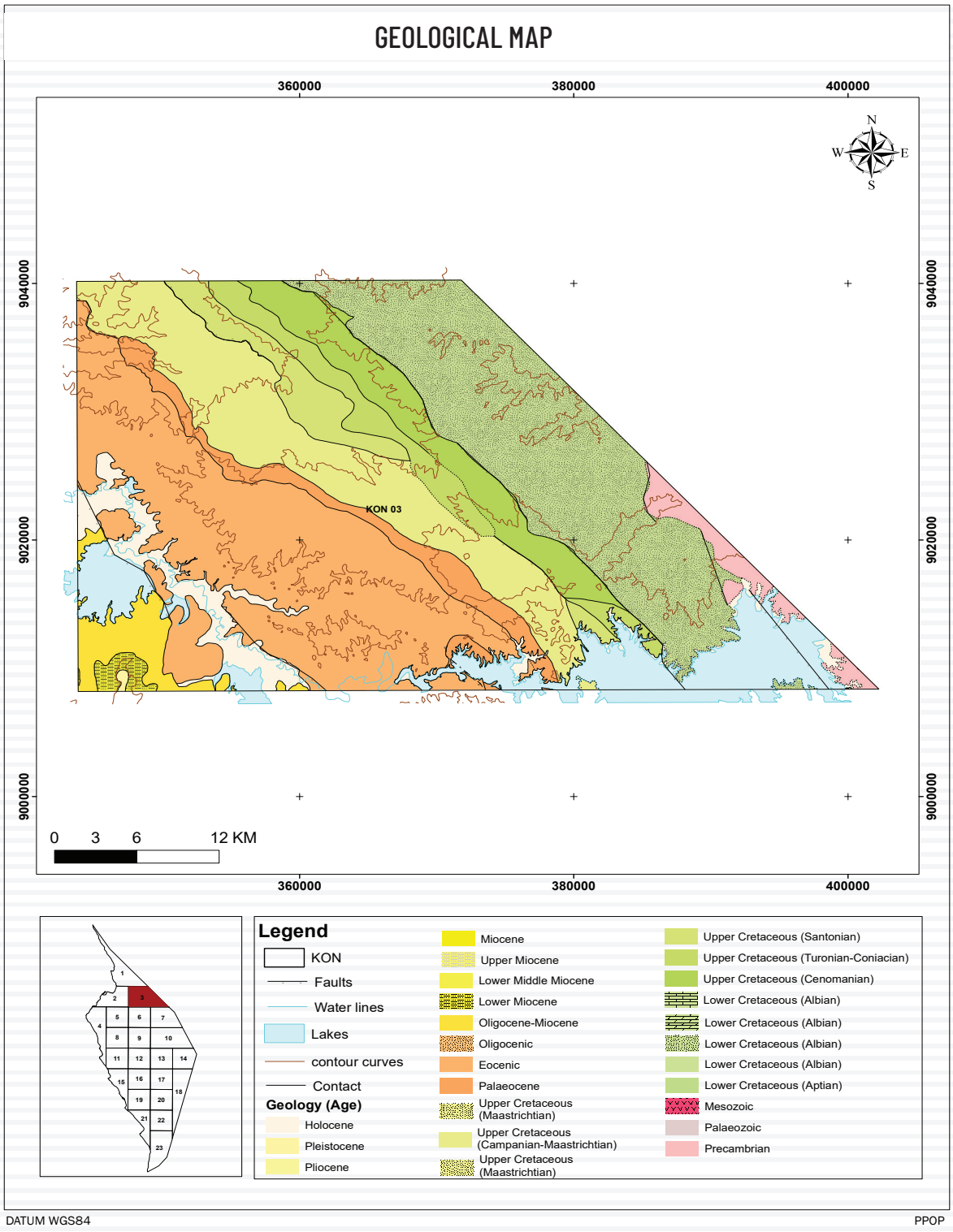

Figure 2: Geological map of Block KON 3, ANPG 2022

Pre-salt Unit

The Pre-salt unit is characterized by horsts and grabens type structures and faults eradicated in the basement throughout its extension, with a more extraordinary accentuation of horst-type structures in the east of the Block than the graben visible further west. In these deeper "structural lows, " there is a more outstanding sedimentary contribution and potential for organic matter accumulation and hydrocarbon generation. The faults system in this unit acts as migration pathways. The reservoirs are on top of the horst (lacustrine carbonates) and Sag phase (sands and microbial carbonates).

In the early Aptian, a lagoonal depositional system developed with the influences of the first marine incursions and high temperatures. The massive salt layer was deposited and constituted the primary seal rock. The probability of the existence of salt windows will enable the migration pathways of hydrocarbons from the pre-salt to the post-salt.

Post-salt

The post-salt unit is represented by post-depositional extensional structures resulting from salt tectonics and sedimentary overburden, forming a systematic series of normal faults of lithic growth and structures in rollovers limited by faults at the Albian level.

The organic-rich Albian age limestone sediments, "calcilutites" with the most significant predominance in this unit, present high potential for a generation that, through lateral facies migration, feed the fractured oolitic limestone reservoirs of the Binga Formation. As seal rock, the salt of the Tuenza Formation and the Cenomanian age shale of the Cabo Ledo Formation, in a mixed type of trap.

The Upper Cretaceous is poorly structured, with more excellent distribution to the west of the Block, represented mainly by sediments of the pelagic type, such as marl, gray shale, brown limestones, and micaceous siltstones, resulting from the marine transgression, and the sandstones deposited during the minor marine regressions. In the Upper Cretaceous, the shale of the Cabo Ledo Formation is the primary source rock.

The Tertiary is characterized by the Funda Trough to the west, with a predominance of potential reservoir sands in the Quifangondo Formation. The black marls of the Cunga-Gratitude Formation act as a source, while the intraformational shale of the Quifangondo Formation may serve as seal rock.

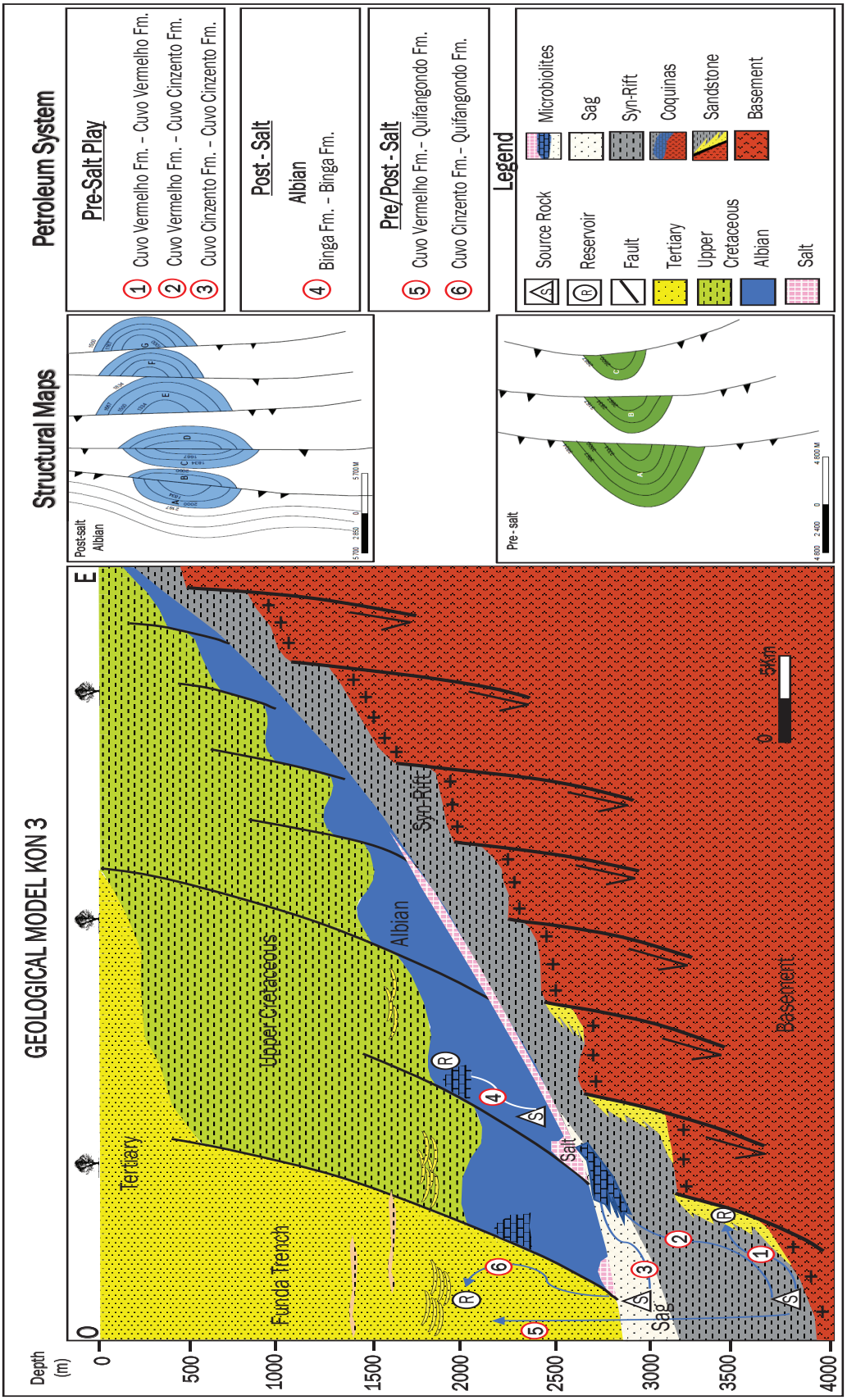

Figure 3: Geological model of Block KON 3, ANPG 2022

4. **EXPLORATION** History

The first exploration work in the Block dates from 1910 to 1973, with a seismic acquisition by the company Petrangol. In 1998, the ENI company conducted aero gravimetry and magnetometry surveys.

The first commercial discovery of oil in the Kwanza Basin occurred in 1955, resulting from the drilling of the Benfica-1 well, known as the Benfica field. Other findings followed, represented by the Luanda, Cacuaco, and Galinda fields.

In July 1961, in the continuation of the work started by the Research Mission, the then-operating company Petrangol discovered the first significant field, the Tobias field, in the Cabo Ledo region, which guaranteed Angola's self-sufficiency in terms of crude oil and also contributed to ending the skepticism regarding the existence of the precious 'black gold' in the Angolan subsoil. The peak of exploration activity was primarily driven by the discovery of the Quenguela Norte field, which represents the new play of the Tertiary. In that same decade, the Mulenvos field was also discovered.

By the end of the 1970s, the Légua and Bento fields had been added to the Inner Kwanza Basin discoveries.

In Block KON 3, there is no record of wells drilled; however, previous studies reveal the existence of hydrocarbon exudations at the surface (upper Quilengues area) near the outcropping of the crystalline basement (ECL, 2003). Therefore, the evaluation of the Block was done from correlations with the Funda-1, Funda-2, Funda-3 and Funda-4, and Calomboloca-1 wells of the KON 2 and KON 6 Blocks, respectively.

In 2009-2012 Geokinectics acquired 65.8 line km of seismic.

Recent geological mapping and surface geochemistry studies were carried out by Sonangol in partnership with Obrangol 2010-2015 and Previsão Oil 2012-2015 (Figures 4, 5, and 6).

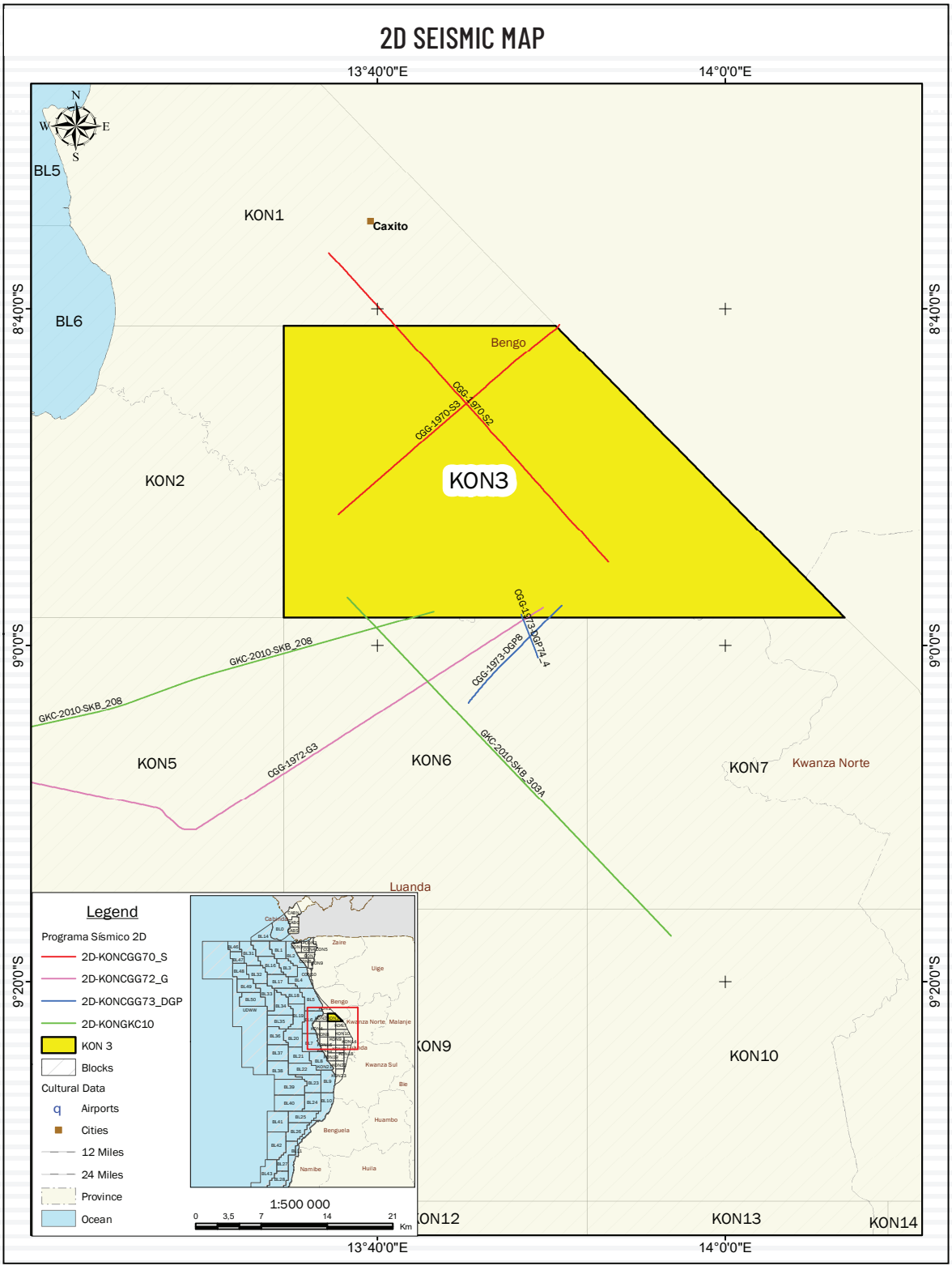

Figure 4: 2D Seismic Data acquired on Block KON 3, ANPG 2022

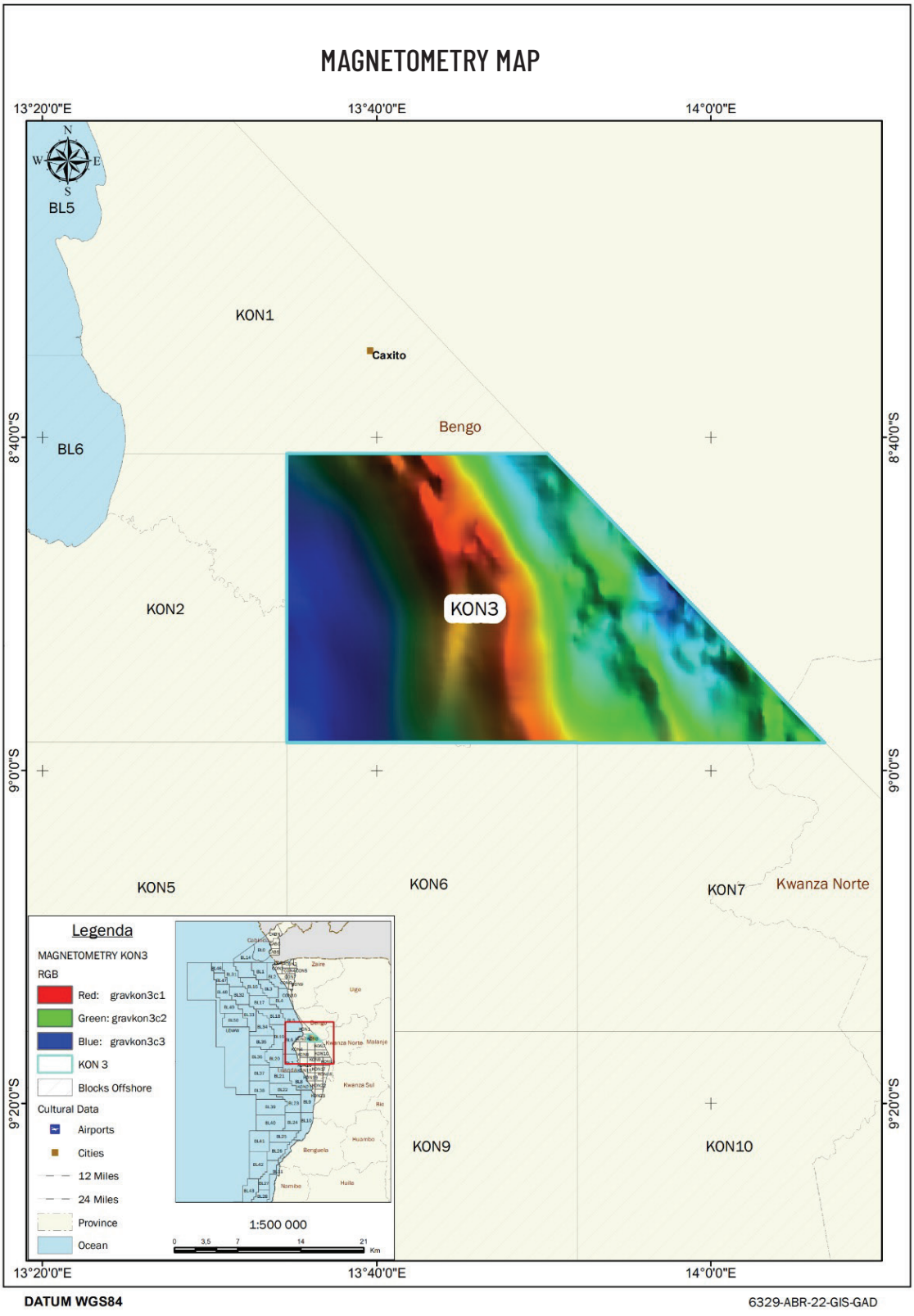

Figure 5: Magnetometry map of the KON 3, ANPG 2022

5. **PETROLEUM** System

With the integration of geological e geophysical data, it was possible to determine the lithostratigraphy and the description of the petroleum system of the two mega-sequences (Pre-salt and Post-salt).

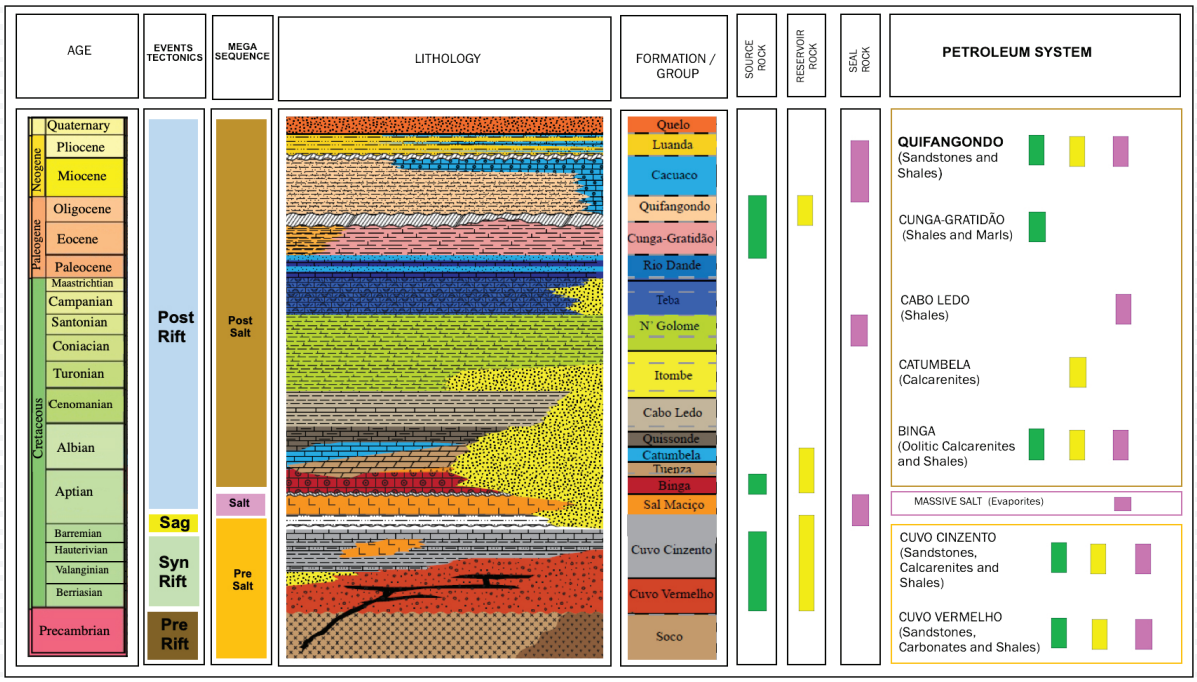

Figure 6: Lithostratigraphic Column of the Onshore Kwanza Basin, ANPG 2022

5.1 Generation and Migration

The source rock consists of organic-rich lacustrine shale of the Cuvo Formation in the Pre-salt, carbonates from Binga Formation in the Albian, and black marls of the Cunga-Gratitude Formation in the Tertiary. Migration pathways occur from faulting, salt window, and facies contact.

5.2 Reservoir Rock

The Cuvo Formation consists of coquinas on top of the horsts and sands on the flanks, and on top of the Barremian are the potential reservoirs at the pre-salt level. The main reservoirs identified in the post-salt correspond to the oolitic limestone of the Binga Formation, the sandstones of the Itombe Formation, and the clastic of the Teba Formation of the middle Cretaceous.

5.3 Seal Rock

The primary seal rock consists of massive salt (Aptian), predominantly halite and anhydrite, in the pre-salt unit. For the post-salt unit, the shale and marls of the upper Itombe Formation and the intraformational shale of the Teba and Rio Dande Formations constitute the primary seal rocks.

5.4 Trap

They were identified in the pre and post-salt anticlinal anticlines structures and rafted only in post-salt, with mixed-type traps occurring in both lithostratigraphic units.

5.5 Source Rock Occurrence

The primary source rocks identified in the Kwanza Basin are the pre-salt organic-rich lacustrine shales of the Cuvo Vermelho and Cinzento Formations and the post-salt carbonates, black marls of the Binga Formation as well as the Cunga Gratidão Formation. The geochemical data from Block KON 6 allowed us to assess the potential of the source rocks. Total Organic Carbon (TOC), Rock-Eval Pyrolysis, and Vitrinite Reflectance analyses were performed in the pre-salt and post-salt units. The Calomboloca Graben shared between Blocks KON 1 and KON 6 revealed average mature stage organic content values. At the post-salt level, the characterization of the Binga source rock suggests excellent mature-stage organic content.

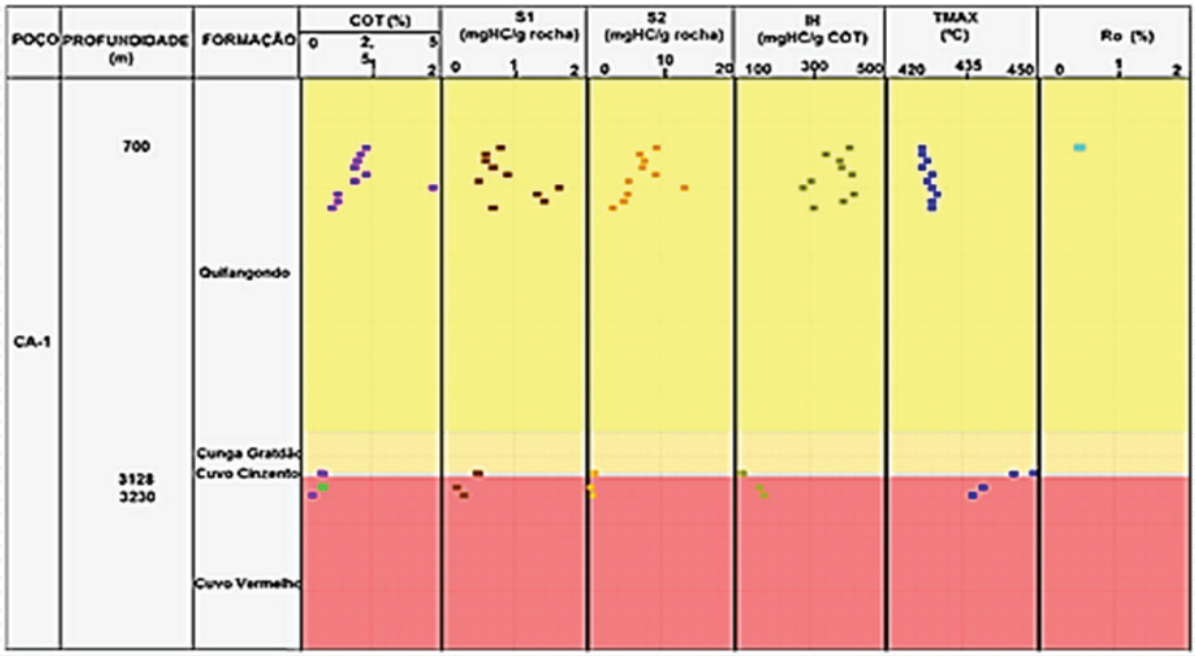

Figure 7: Geochemical Log of the well CA-1

Cuvo Vermelho Source

The shale of the Cuvo Vermelho Formation identified in the Calomboloca graben in well CA-1 at a depth of 3 290 meters shows average values of total organic content (TOC) 0.5, HI values 175 mgHC/gCOT indicate type III kerogen, the parameter indicating maturity Tmax 437 °C shows that the rock is in the mature stage.

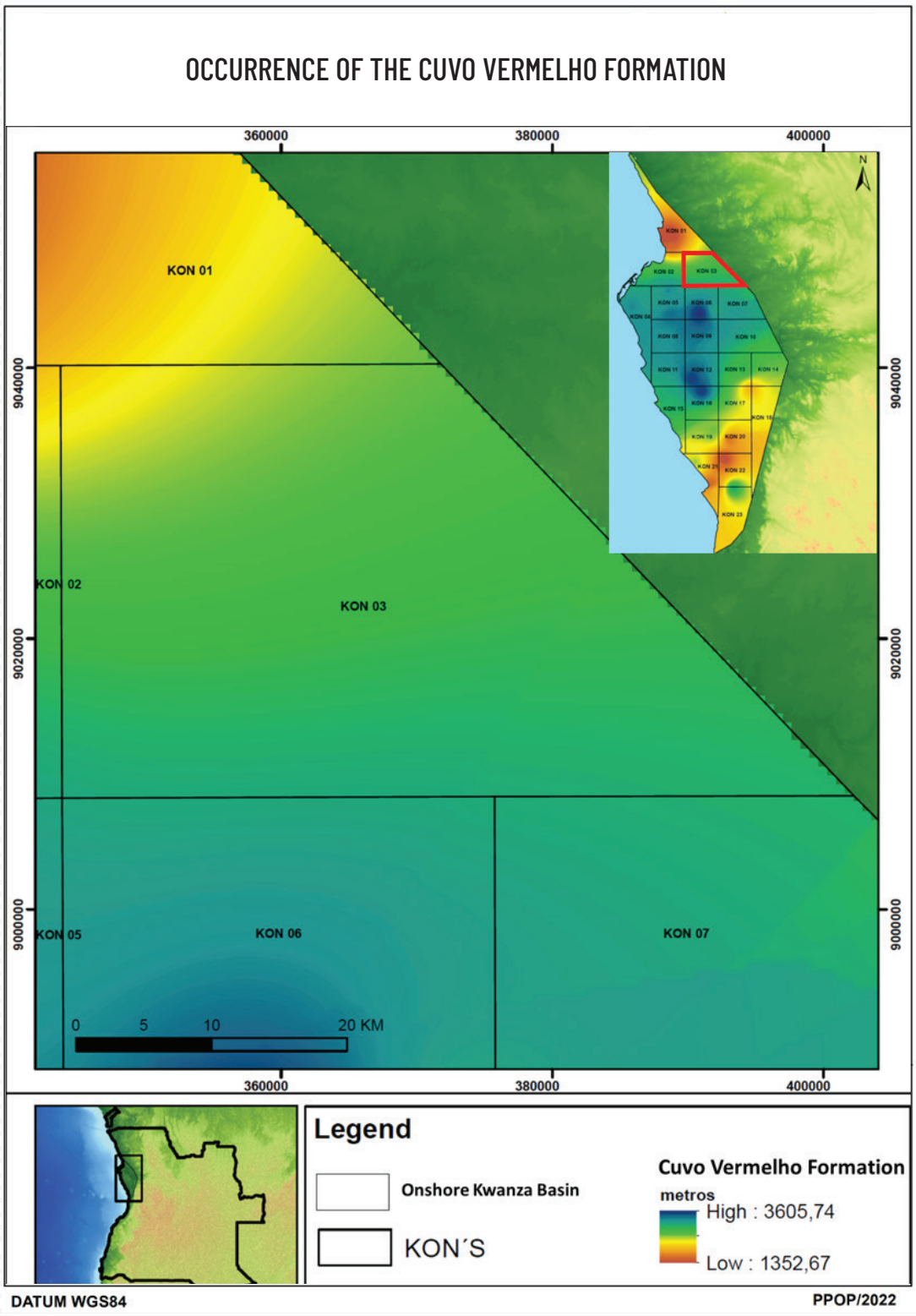

Figure 8: Occurrence map of Cuvo Vermelho Fm. Source rock

Cuvo Cinzento Source

The shale of Cuvo Cinzento Formation identified in well CA-1 at a depth of 3126 – 3128 m shows average values of total organic content (TOC) 0.7- 0.75%, HI values 115-120 mgHC/gCOT indicating kerogen type II/III, the parameter indicative of maturity Tmax 445-449 °C suggesting that the rock is at the peak of the oil window.

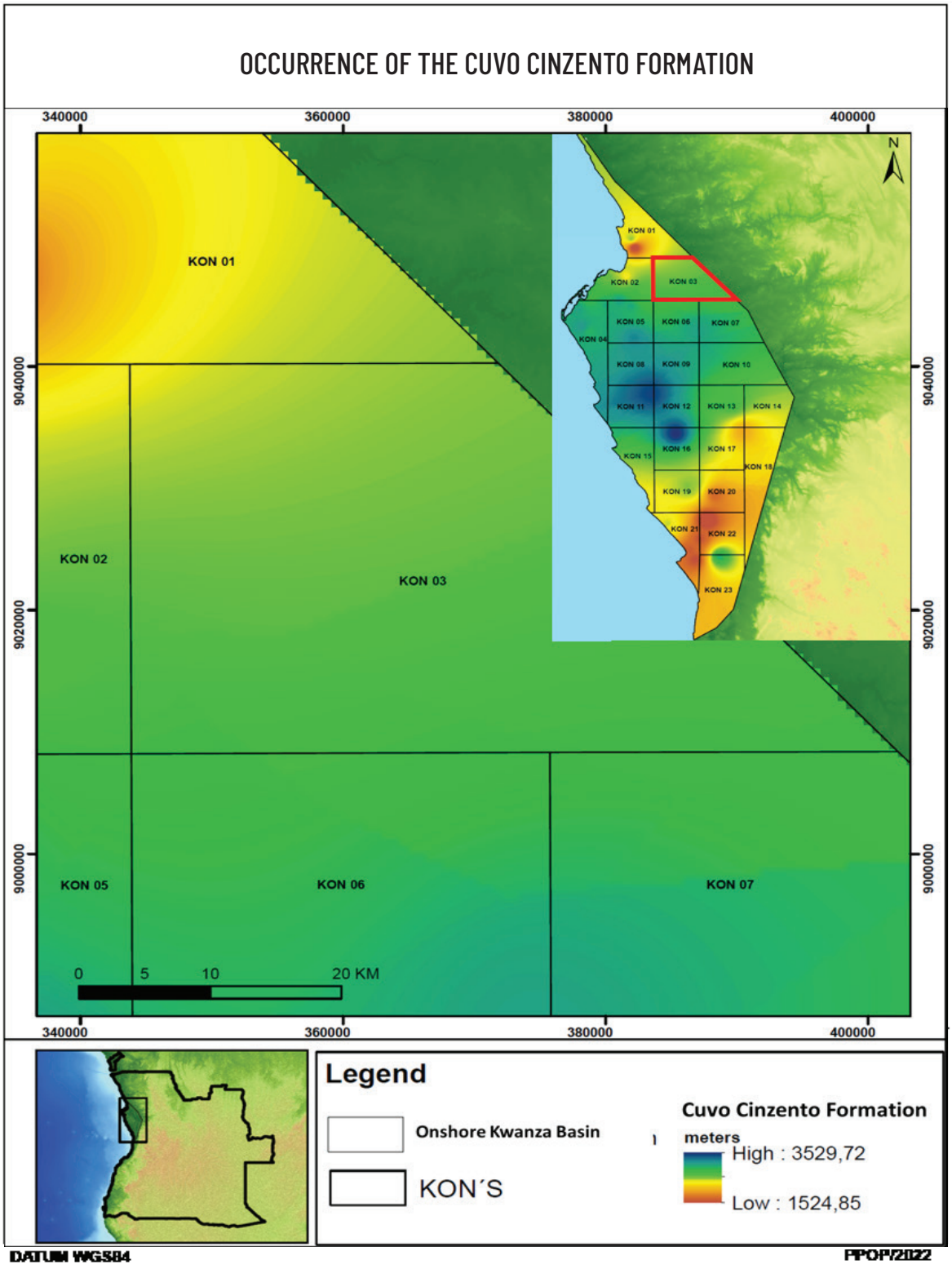

Figure 9: Occurrence map of Cuvo Cinzento Fm. Source rock

Binga Source

Carbonates of the Binga Formation, a proven Albian source rock, are entirely distributed over the block. Studies conducted in Block KON 11 prove its geochemical potential.

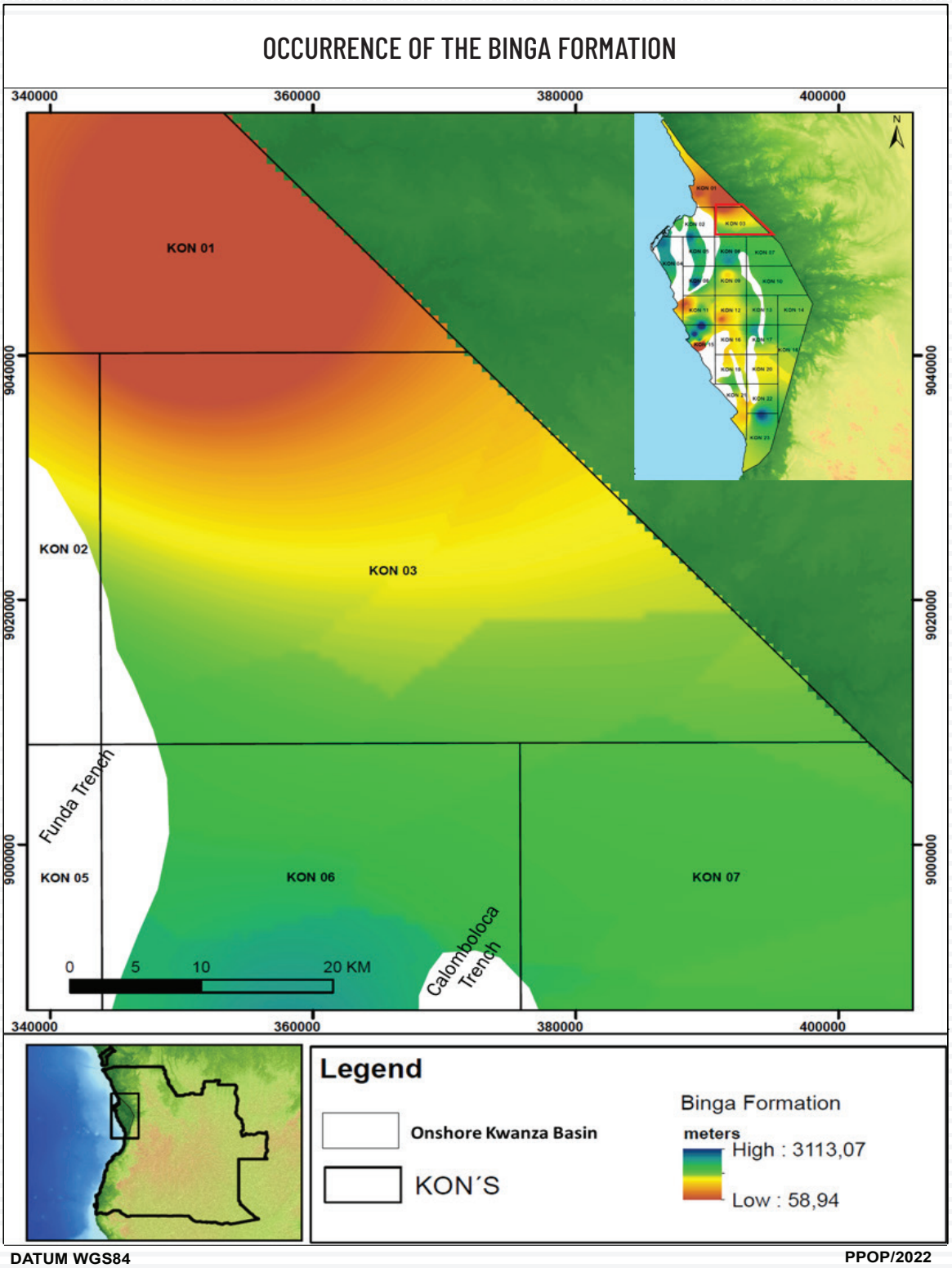

Figure 10: Occurrence map of Binga Fm.

1D Model

The Calomboloca-1 well shows that the Cuvo Vermelho Formation was deposited in the Lower Cretaceous. The thermal evolution of the generating facies at 1 000 to 2 500 m reached the oil window from Upper Cretaceous to the Oligocene and the gas window at depths of 2 500 to 4 000 m from Oligocene to the present. On the other hand, the Cuvo Cinzento Formation was deposited in the Lower Cretaceous, having reached oil window depths of 1 000 to 2 400 m in the Upper Cretaceous to Oligocene and gas window depths of 2 400 to 3 800 m from the Oligocene to Present Day.

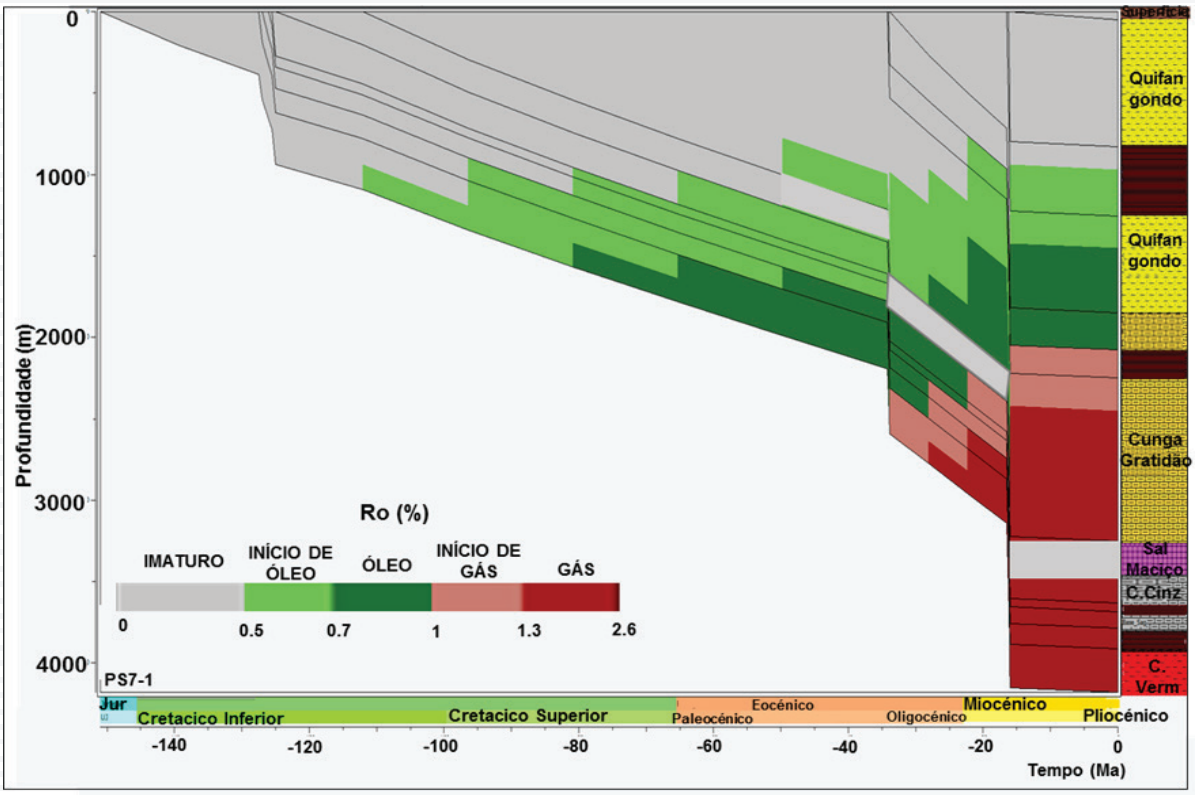

Figure 11: Maturation profile of Calomboloca-1 well, ANPG 2022

6. **EXPLORATION** Opportunities

6.1 Identified Leads

The geological and geophysical data acquired allowed the identification of the pre-and post-salt leads described below.

6.1.1 Pre-salt Leads

This model is confirmed from a geophysical point of view by interpreting gravimetric and magnetometry data. The pinch-out of the sands layer from the Cuvo Formation on the flank is the potential reservoir fed by the lacustrine black shale source of the Cuvo Formation. This lead has a mixed-type trap (structural and stratigraphic) with a

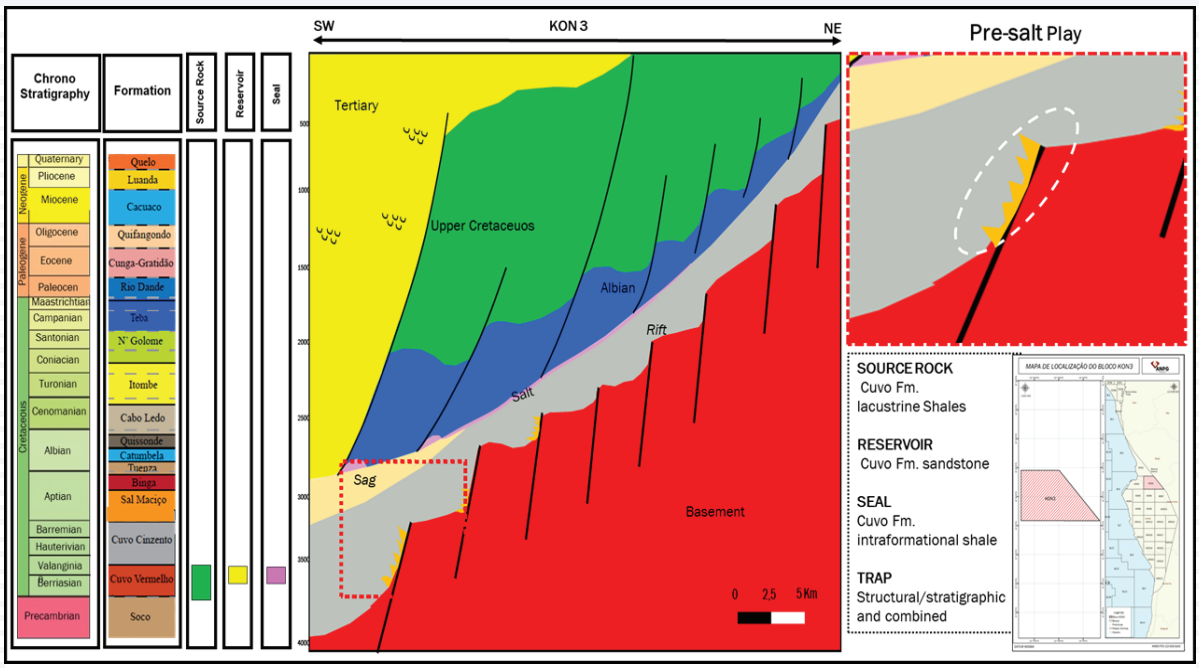

Figure 12: Pinch-out Sandstone reservoir, ANPG 2022

The pre-salt structures are evident in the geological model. They are carbonates from the sag phase sealed by the intraformational shale and charged from mature Cuvo Vermelho pre-salt source facies.

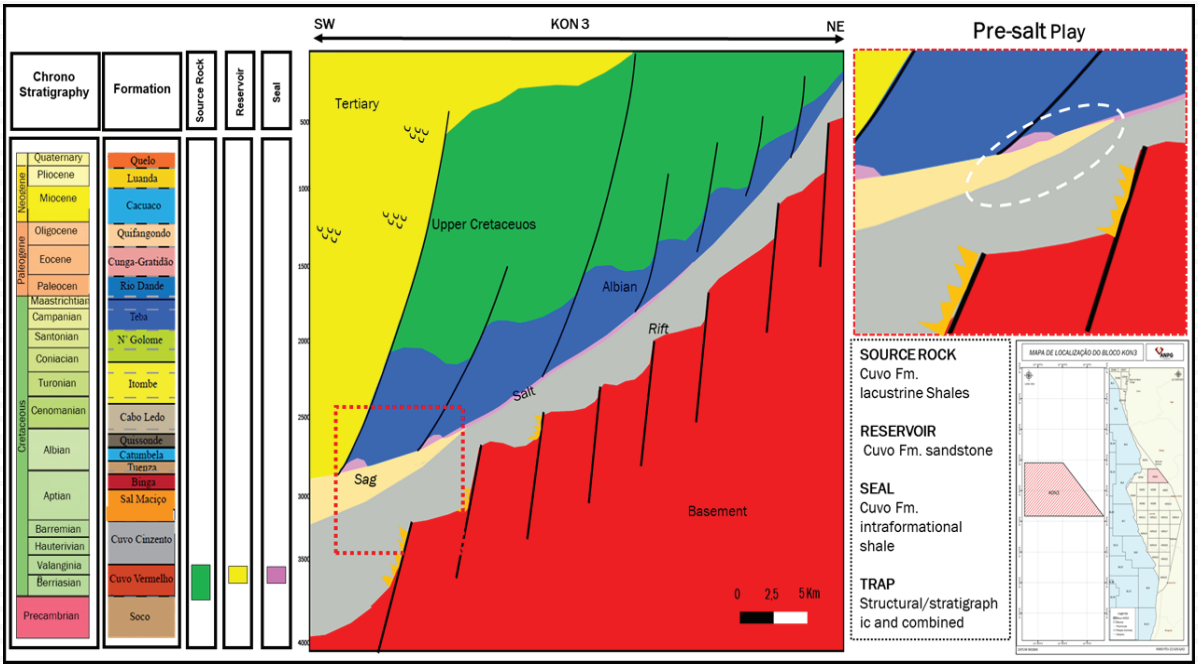

Figure 13: Pre-salt reservoir, ANPG 2022

6.2 Post-salt Leads

The Albian's play is characterized by oolitic carbonates reservoirs from the Binga Formation, potentially filled by hydrocarbons generated in the Binga Formation shales and mixed trap influenced by the faults that may have compartmentalized the reservoirs and stratigraphically sealed by the intraformational shales from the Cabo Ledo Formations.

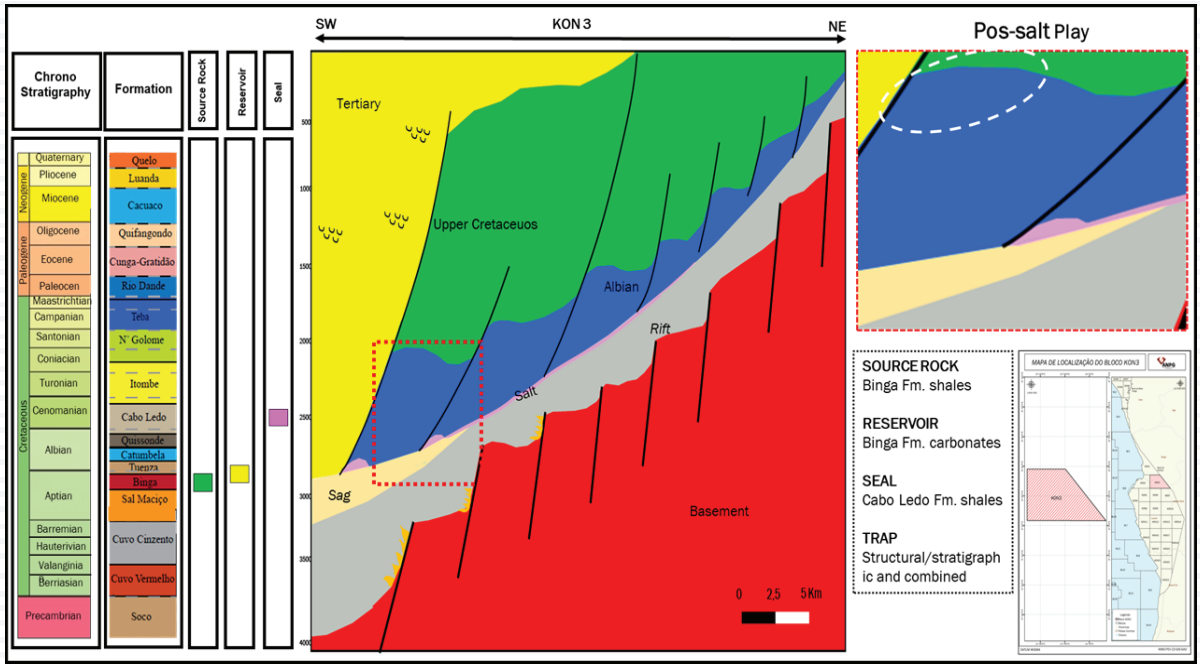

Figure 14: Albian Oolitic limestone, ANPG 2022

The sandstone facies of the Turonian-aged Itombe Formation with high reservoir potential at the Upper Cretaceous level, the organic-rich shale of the Cabo Ledo Formation represent the source rock and as seal rock, the intraformational shale of the Itombe Formation.

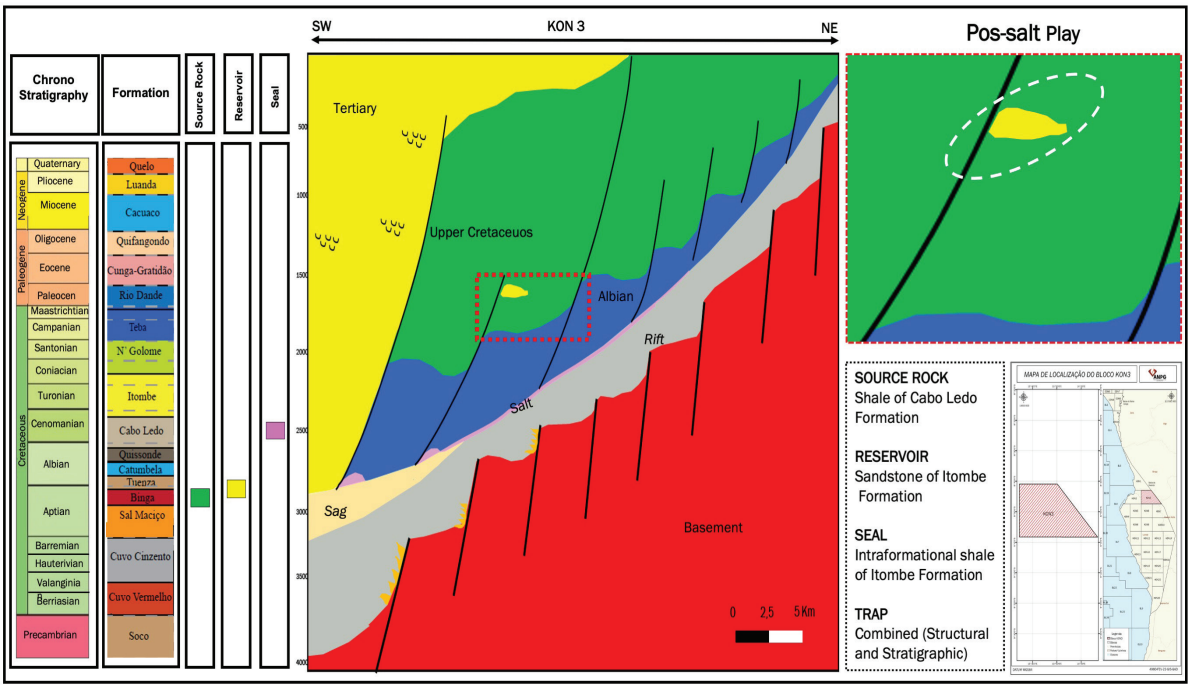

Figure 15: Sandstone reservoir from Itombe Formation, ANPG 2022

At the Tertiary level, sandstone channel reservoirs of the Quifangondo Formation, fed by source rock consisting of black shales of the Cunga-Gratitude Formation, deposited at the base of the Calomboloca trough. The overlying intraformational shale represents the seal rock for these reservoirs in mixed-type traps.

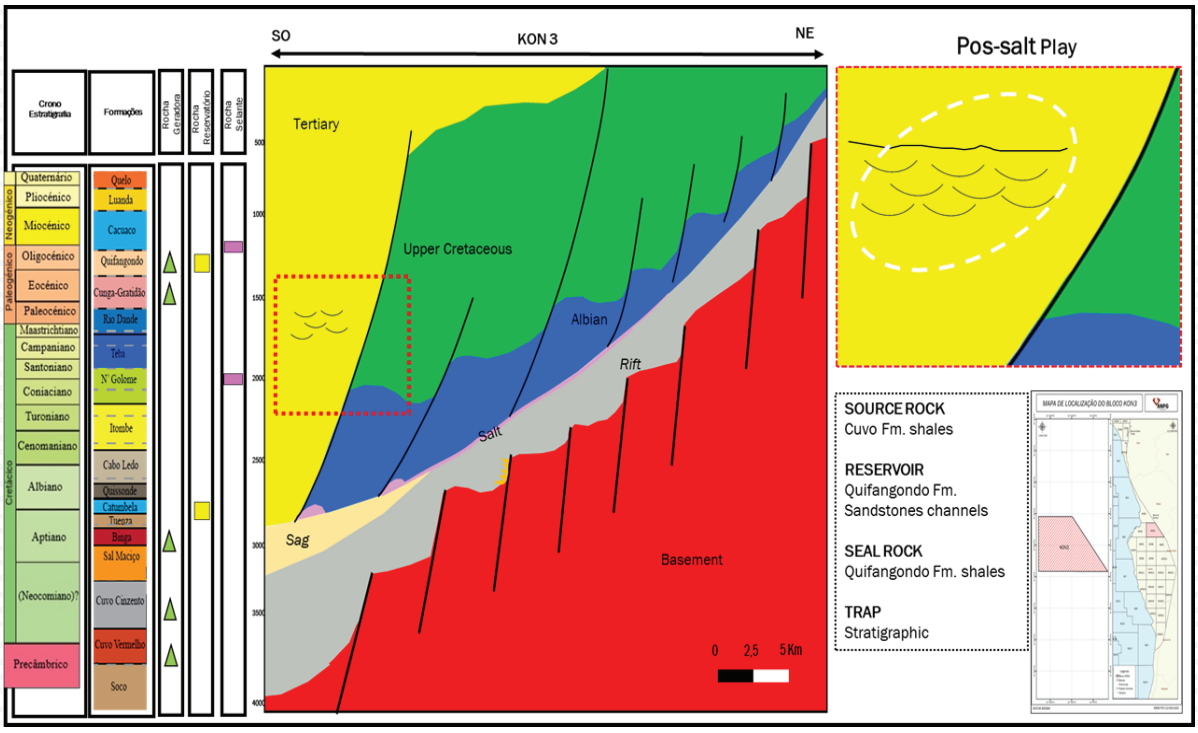

Figure 16: Tertiary sandstone channel, ANPG 2022

7. **FINAL** Remarks

After reassessing the block KON 3, it became evident that Inner Kwanza Basin has a solid potential to be exploited in pre-salt and post-salt plays in a region widely known as having a proven, functional, and active petroleum system.

In the Pre-salt, the primary source rock is the Cuvo Formation, equivalent to the Bucomazi in the lower Congo Basin. The reservoirs are the sands and carbonates of the same formation equivalent to the Lucula, Toca, and Chela Formations in the lower Congo Basin.

In the post-salt, the Albian age carbonates of the Binga Formation are the primary source rock, and the carbonates of the same formation are the reservoir rock. In the Tertiary, the source rock is the black marl of the Cunga-Gratidão Formation, and the reservoir is the sandstone channels of the Quifangondo Formation.

The ANPG encourages the companies to invest in this block through additional studies to ensure the discovery of the real potential, which should allow for the boosting of exploration activity aiming to revert the production decline observed over the last decade.

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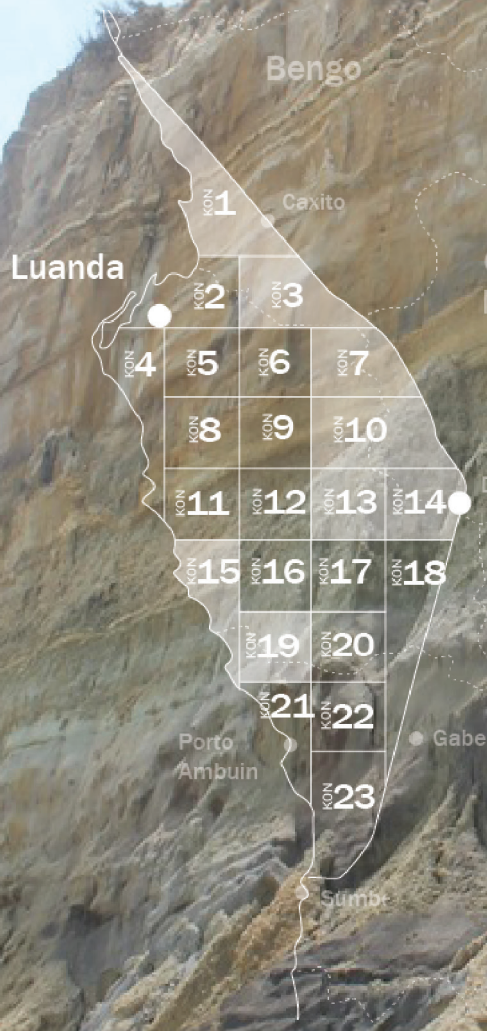

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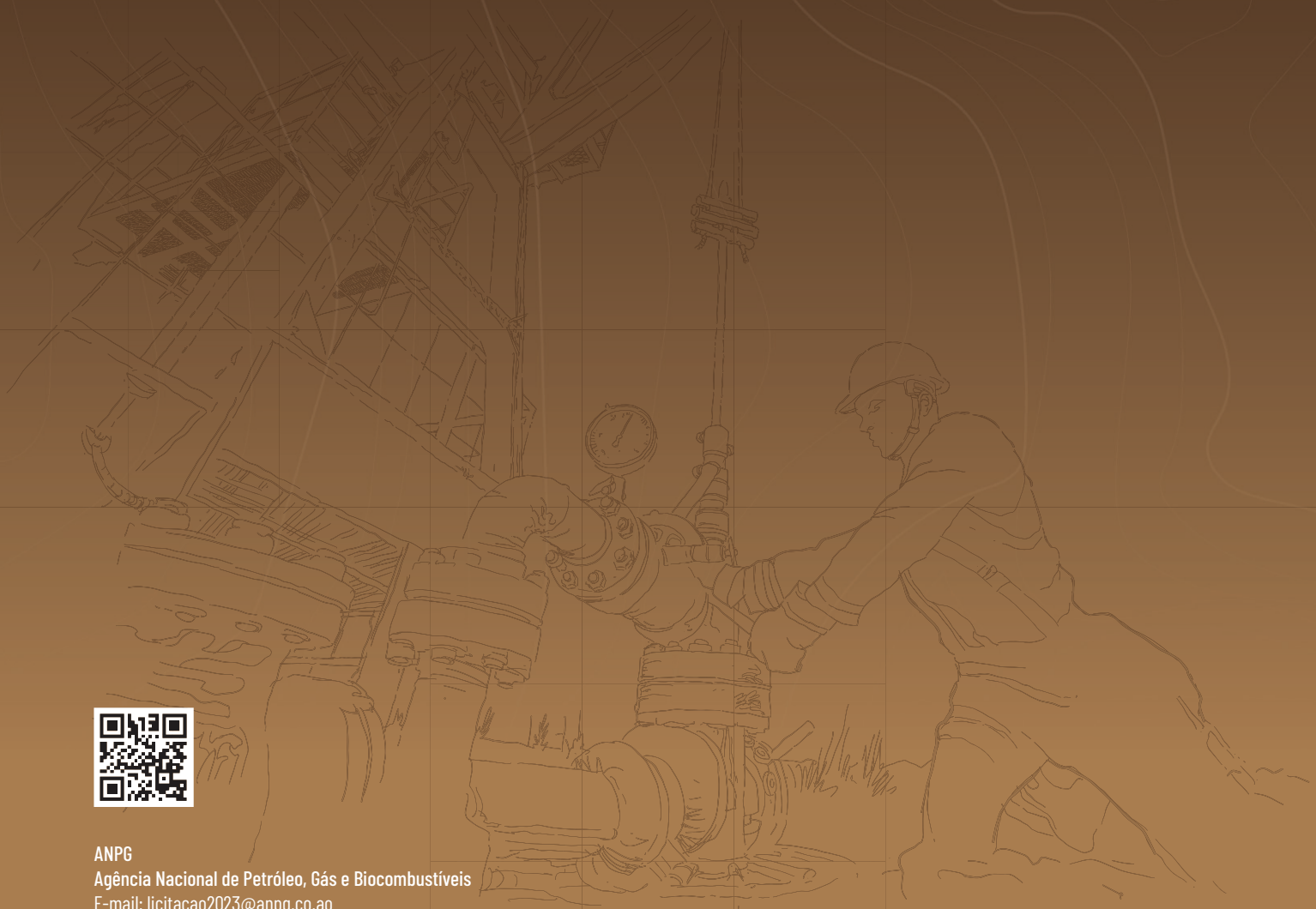

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