CHAPTER 2

SEDIMENTOLOGY & STRATIGRAPHY

INTRODUCTION

Objectives

The objective of Chapter 2 is to update the stratigraphic framework of the Moroccan shelf in order to refine potential links with the Nova Scotia (Canada) margin.

Results of the study are:

• An update of the stratigraphic chart linked to and adapted with the Nova Scotia margin. This chart is based on regional published literature and the current study (PL.2-3);

• An update of the correlation panel of Transect 2 from DSDP-415 to AGM-1 wells (PL. 2-4), which have been chosen as representative of the deep offshore to platform sedimentary transition,

• Creation of 4 burial history diagrams based on wells DSDP-416, AGM-1, AMBER-1 and FA-1 (Transect 2) (PL. 2-5).

Well Database and Methodology

The well database consists of 9 key wells (Table 1) distributed offshore northern Morocco from the shelf to deep water (Figure 1). These wells are used to refine the lithostratigraphy and sequence stratigraphy of the area.

• *Well lithology and petrophysics*

No petrophysical interpretations were performed for this project. Only initial log data have been used and all wells presented good log sets. Lithologies have been interpreted from cuttings.

• *Biostratigraphy in wells*

Detailed biostratigraphic analyses were performed on a total of 10 wells; see Weston (2019) for more information.

• *Well correlation*

One correlation panel is here used to create a better understanding of the Moroccan margin. This transect is based on Transect 2 and includes four wells from DSDP-415 to AGM-1. This work served as input for the geophysical interpretation of the key horizons and the basin modelling.

Well ID	Operator	Year	Location	Latitude	Longitude	KB (m)	WD (m)	TD (m)	TD Geological age
AGM-1	Arco	1982	Offshore	30°14'46.9000"N	9°55'20.2000"W	15	158	1716	Toarcian
AGM-2	Arco	1983	Offshore	30° 14' 17.8" N	9° 52' 59.8" W	15.24	140	1983	Lower Jurassic
AMBER-1	Shell	2004	Offshore	30°19'23.5689"N	10°54'27.0879"W	38.2	1987	5570	Albian
CAP-JUBY-1	Mobil	1984	Offshore	28° 17'32" N	13°01'48.6"W	30	105	4798	Lower Jurassic
DSDP-415	?	1976	Offshore	31°01'72.0000"N	11°39'11.0000"W	10	1797	1079	Upper Albian
DSDP-416	?	1976	Offshore	32°50'18.0000"N	10°48'6.0000"W	?	4193.4	1624	Upper Jurassic
FA-1	Kosmos	2014	Offshore	30°19'22.5728"N	10°10'51.2973"W	32.5	632.5	3830	Und. Cretaceous
FD-1	Cairn	2013	Offshore	29°27'14.8127"N	11°33'1.7260"W	22	1576.5	5255	Callovian
TAN TAN-1	Amoco	1985	Offshore	29° 00' 53" N	11° 40' 50" W	30	128	5069	Callovian

Table 2.1: Selected wells for the stratigraphic framework study: 8 key wells used in the transects and 5 wells for regional understanding.

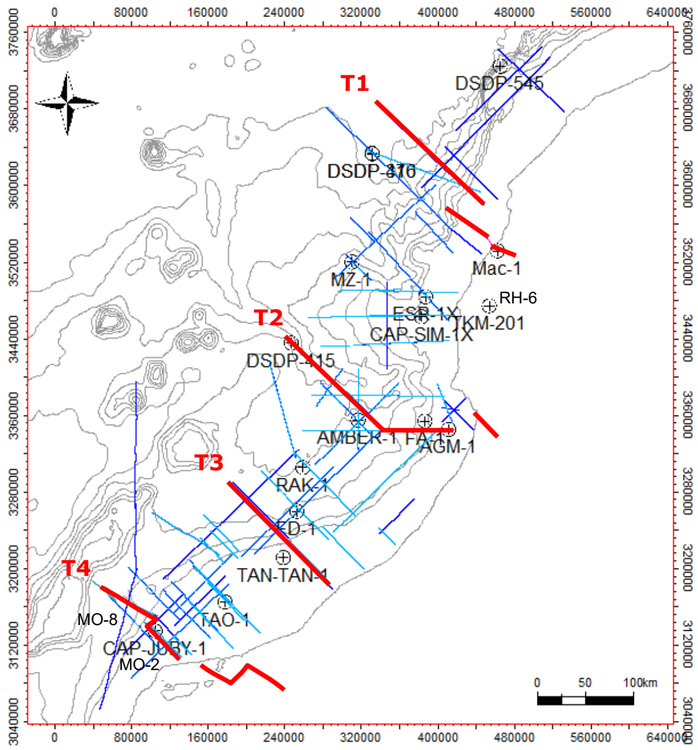


Figure 2.1: Wells and key transects location across the Moroccan shelf.

In total, 9 wells were used for this study. They all have a complete well log dataset (GR, NEUT/DEN, DT…) that can be used for correlation. Some of the southern wells, for example Cap-Juby-1, presented a sediment thickness in excess of 5000m. The deepest wells are AMBER-1 and MZ-1 with a thickness of sediments approximating 6000m.

Distal wells ← ***Proximal wells***

DSDP-415 (WD : 1800m)
MZ-1 (WD : 2700m)

TAN TAN (WD : 128m)
AGM-1 (WD : 158 m)

Offshore Nova Scotia, the four transects used in the current study correspond to (see Plate PL.0.1):

- Transect 1 in Tantallon area using well DSDP-416
- Transect 2 in Aspy area using wells DSDP-415, FA-1 and AMBER-1
- Transect 3 in Cheshire area using wells TanTan-1 and FD-1
- Transect 4 in Cab Juby area using well Cap-Juby-1

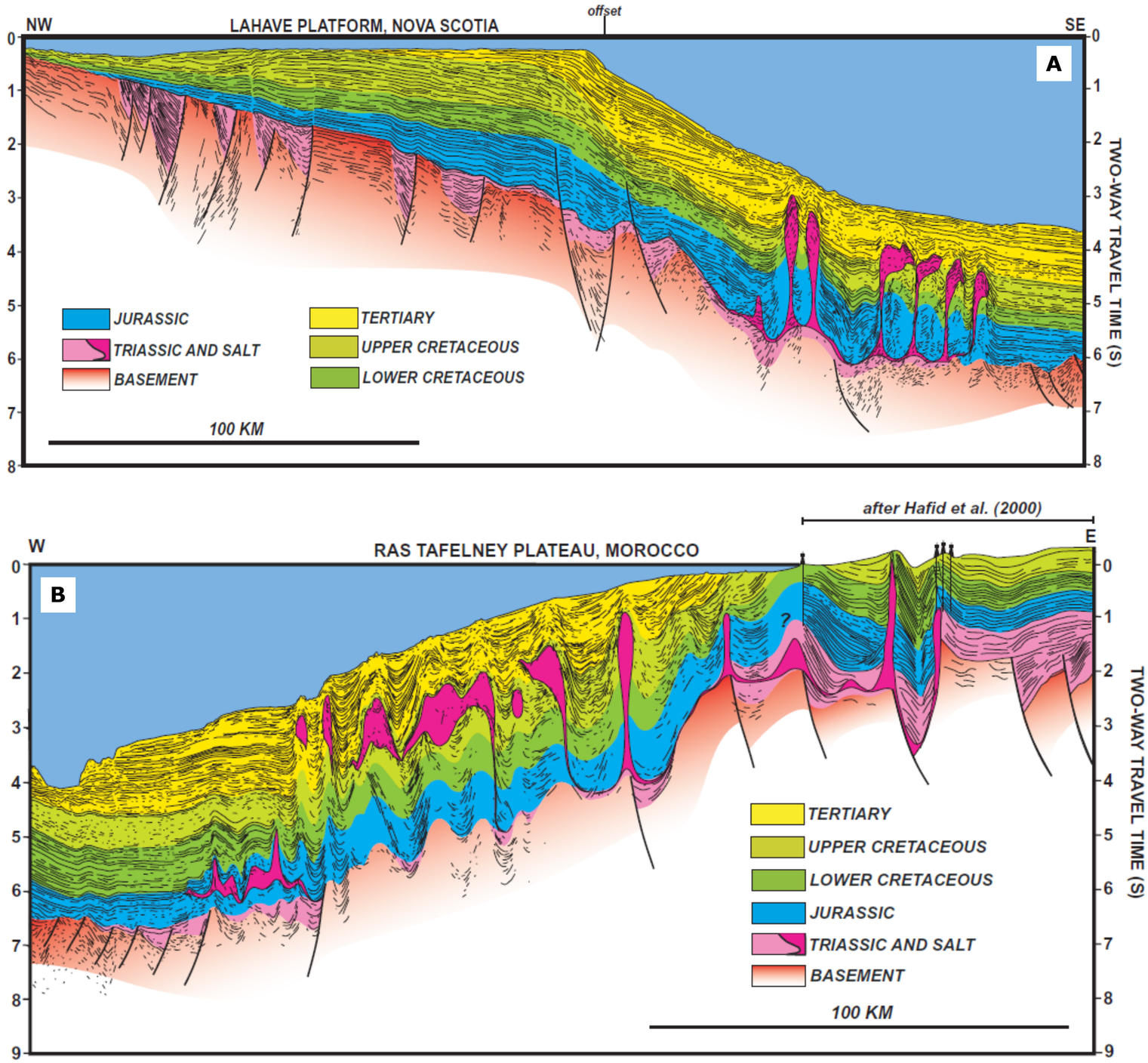


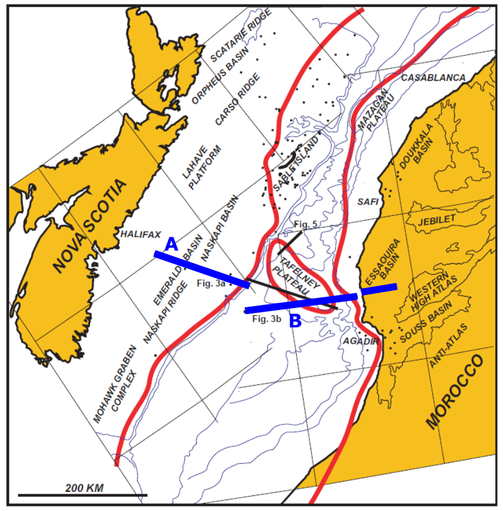
Figure 2.2: Regional cross section interpreted across (A) the La Have Platform of offshore Nova Scotia and (B) the Tafelney Plateau. Vertical exaggeration is about fivefold at 4 km/s velocity. (from Tari et al., 2013)

CANADA - NOVA SCOTIA (Figure 2.2A)

The Canadian margin is much wider than the Moroccan margin, with a very thick overall sedimentary sequence, about twice as thick as the Moroccan margin. The total sedimentary thickness can reach 18 km above the syn-rift basins.

The syn-rift formation is defined by a dominance of landward dipping faults. The salt basin is restricted to the deep-water basin showing relatively advanced salt structures, such as diapirs.

Another striking feature is the presence of a thick (up to 4.5 km) and laterally extensive (occurring for more than 15,000 km^2) Middle to Upper Jurassic package of sediments, which sole out onto the regional salt detachment (Tari et al., 2013).



Location map (from Tari et al., 2013)

MOROCCO - NORTHERN MOROCCAN MARGIN (Figure 2.2B)

The conjugate Moroccan margin has a very thin syn- and post-rift cover.

The regional transect of the Moroccan margin over the Tafelney Plateau shows a wider salt basin compared to Nova Scotia. Whereas there are relatively simple salt diapirs existing onshore, the salt tectonic styles become gradually more advanced going offshore. Several salt diapirs were described from the area outboard of the Plateau on the abyssal plain. Based on their expression on the present-day seafloor, some of these salt diapirs are still active (Tari et al., 2013).

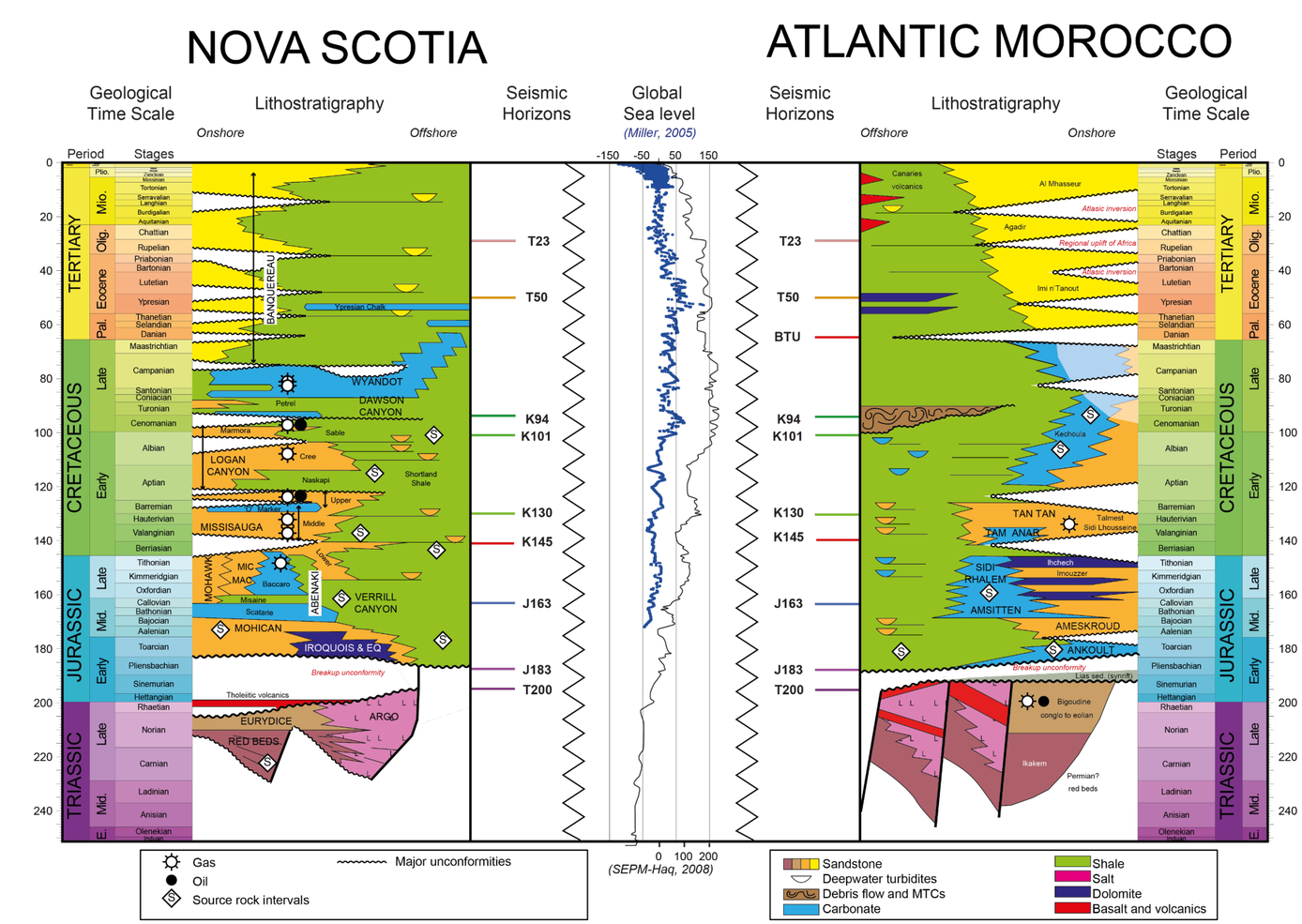


Figure 2.3: Modified Stratigraphic Chart incorporating all sedimentary and geological events as well as interpreted seismic horizons and global sea level.

Regional Geology and Stratigraphic Framework Overview

CONJUGATE ATLANTIC BASINS - NOVA SCOTIA & MOROCCAN MARGIN

Both syn-rift sequences are dominated by continental clastics, salt and some basalt intercalations (200 Ma) (Figure 2.3). The age of the breakup unconformity appears to be late Lias on both margins. Lias sediments are observed on the Moroccan margin (Figure 2.4) underneath the breakup unconformity, while the existence of Lias sediment is still under debate along the Canadian margin. Both margins see the preservation of a widespread Jurassic carbonate platform that was drowned by Early Cretaceous succession.

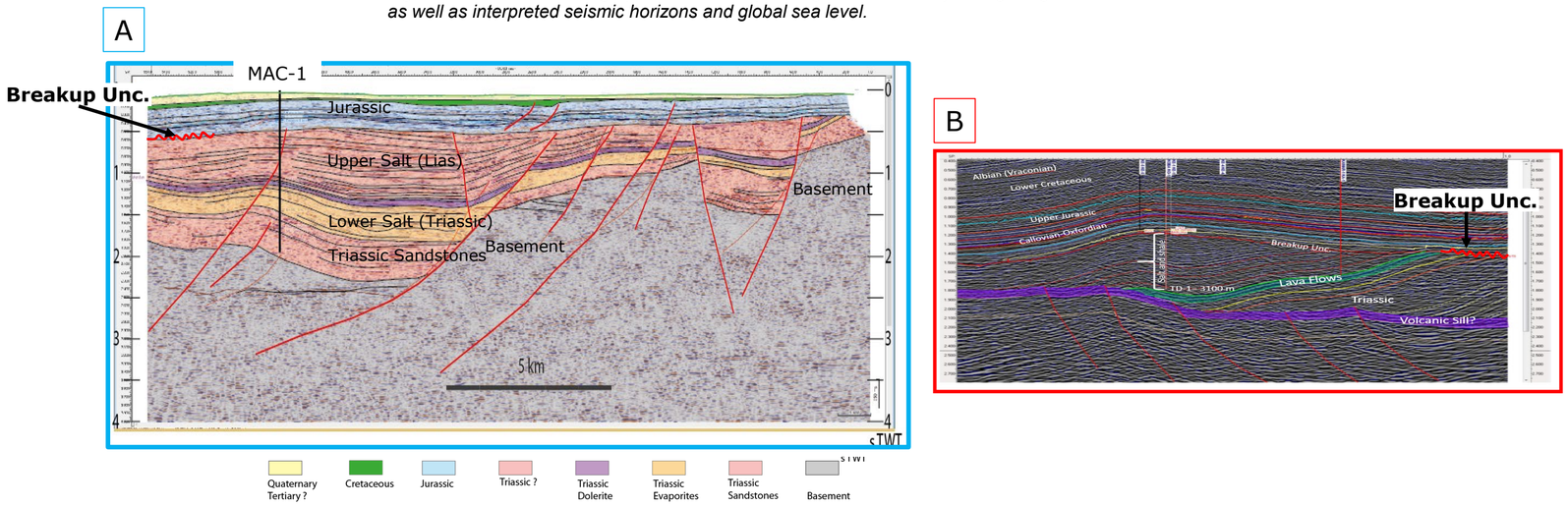
One of the most important differences is the overall amount of siliciclastics delivered across the paleo-shelves of these margins (Figure 2.3). Several major deltas developed on the Canadian margin from Middle Jurassic and extending throughout most of the Cretaceous, whereas, the last major pulse of siliciclastic sedimentation was produced only by the Neocomian Tan-Tan fan delta system in the Moroccan basin. Finally, there was a very important phase of Late Tertiary volcanism on the Moroccan margin (Canary Islands), and in the north in ultradeep water (Tari et al., 2013).

Ten seismic horizons have been interpreted on both margins for this project in order to understand and compare the evolution and filling of the basins between Nova Scotia - Canada and the conjugate northern Morocco margin.

The horizons are :

- T23
- T50
- BTU (only observed along Moroccan margin)
- K94
- K101
- K130
- J145
- J163
- J183
- T200 (Top Autochthonous salt)

TERTIARY (T23, T50)
CRETACEOUS (BTU, K94, K101, K130, J145)
JURASSIC (J163, J183, T200)



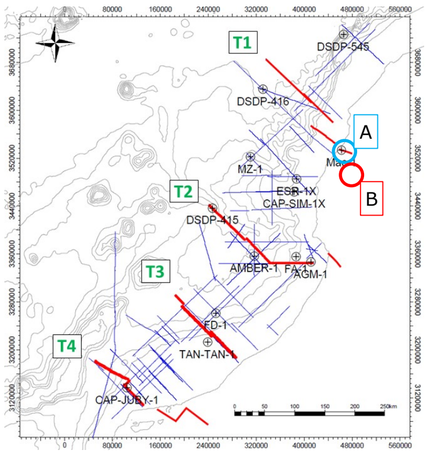


Figure 2.4: A) Onshore seismic line through well MAC-1 and B) onshore seismic line located East to the T1 termination. Both lines are courtesy of ONHYM. See the map for location of the seismic lines (blue and red circles, respectively).

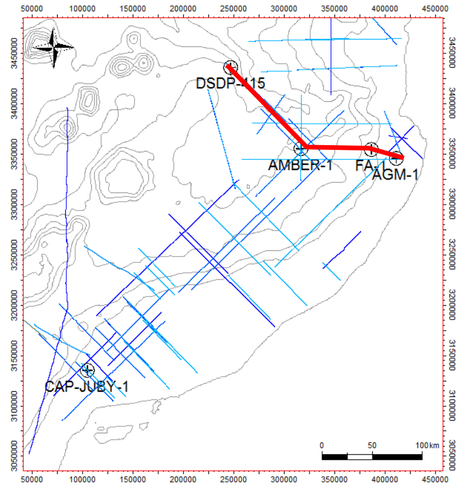


Figure 2.5: Wells and key transect location across the Moroccan shelf for the correlation.

This correlation panel illustrates the dip transition between the oceanic and the continental crust across a wide salt basin (Figure 2.5 and 2.6). It uses 4 wells: DSDP-415, AMBER-1, FA-1 and AGM-1 from proximal to distal position. The pile of sediments (interpretation of ages based on biostratigraphic data) accumulated and preserved within the salt basin (see well AMBER-1) is much thicker compared to the surrounding wells. This is particularly well illustrated for the Tertiary succession.

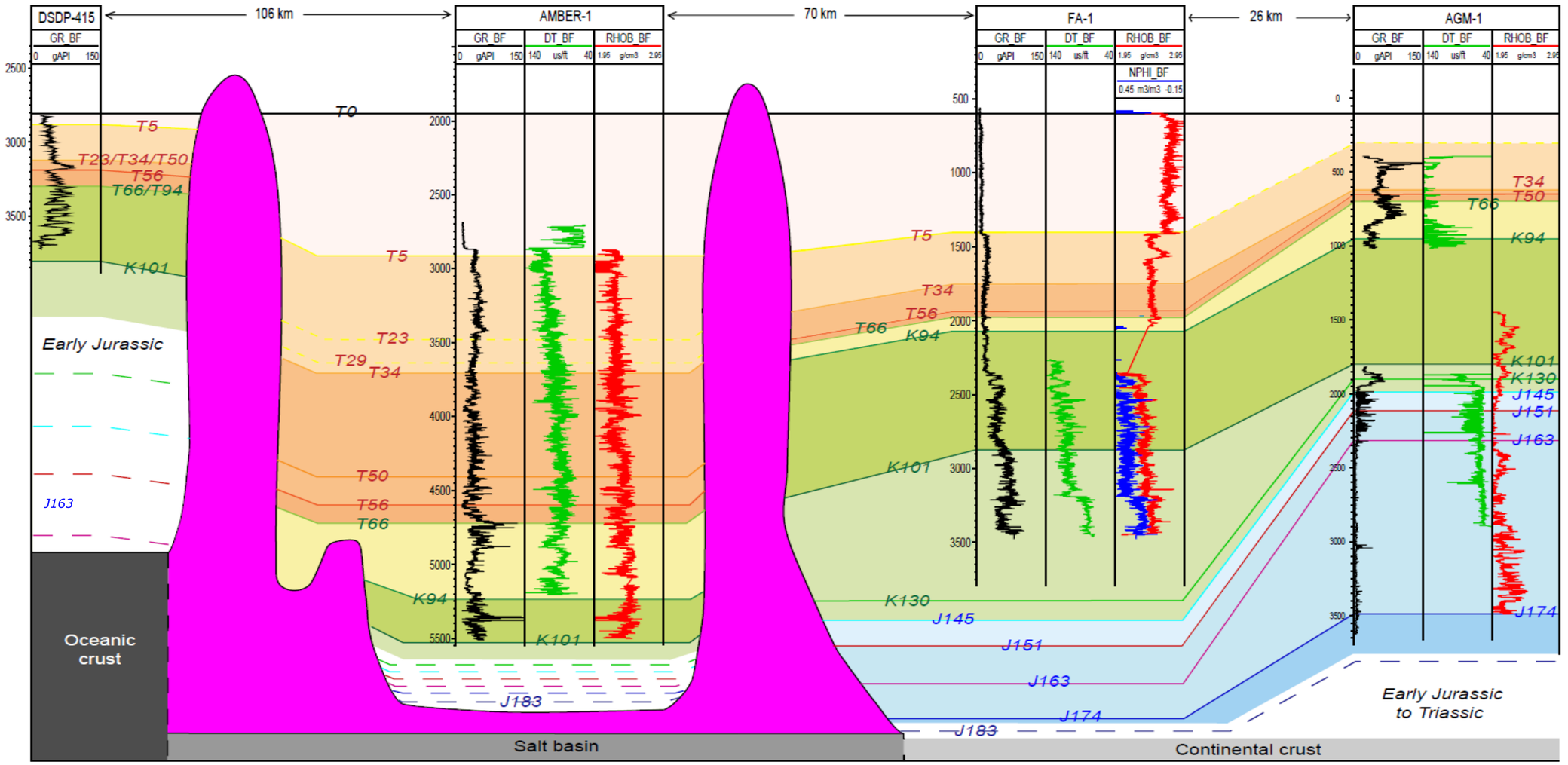
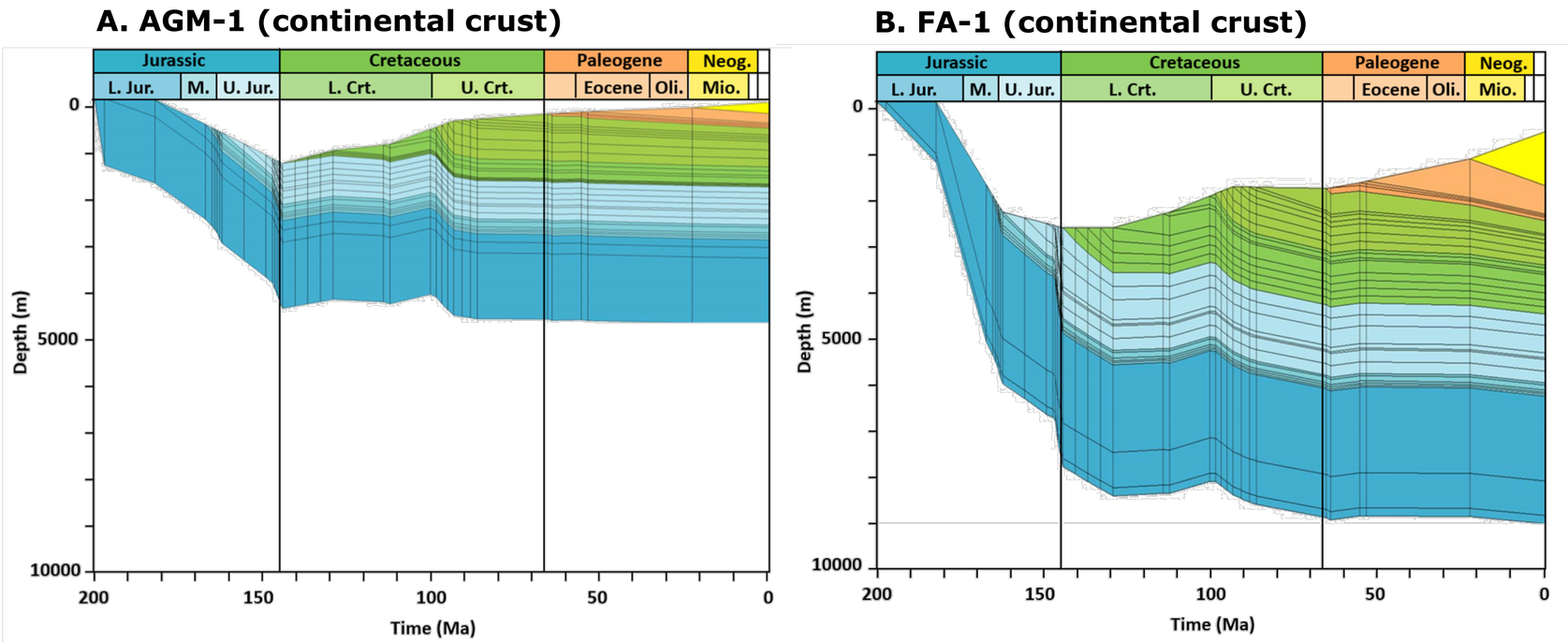


Figure 2.6: Well correlation panel on the Moroccan margin from distal to proximal wells.

PL. 2.4 **Correlation Panel - Transect 2**



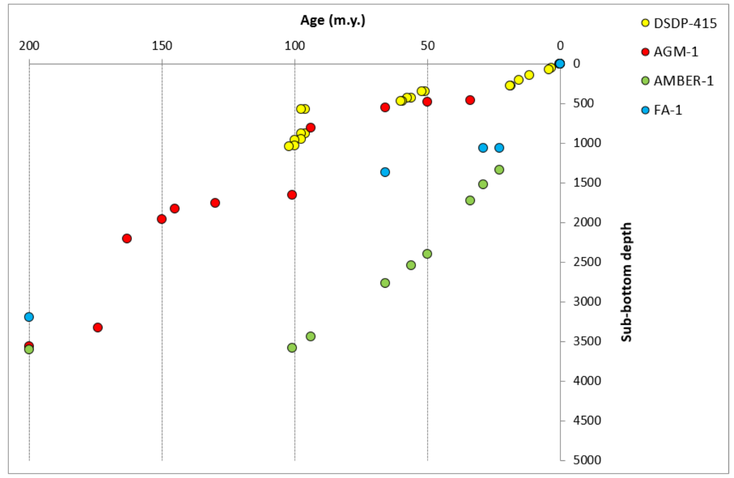


Figure 2.7: Sedimentation rate diagram

As seen along the correlation panel of PL. 2-4, the burial history varies greatly from proximal to distal location along the Moroccan margin (Figure 2.6). Well AMBER-1 (Figure 2.6.C) demonstrates the maximum burial, in relation with a high sedimentation rate (green dots in Figure 2.7). The three other wells shown here are characterized by a more comparable sedimentation rate (wells DSDP-415, FA-1 and AGM-1 in Figure 2.7). AGM-1 and DSDP-415 have similar burial history while FA-1 demonstrates significant burial during Jurassic time.

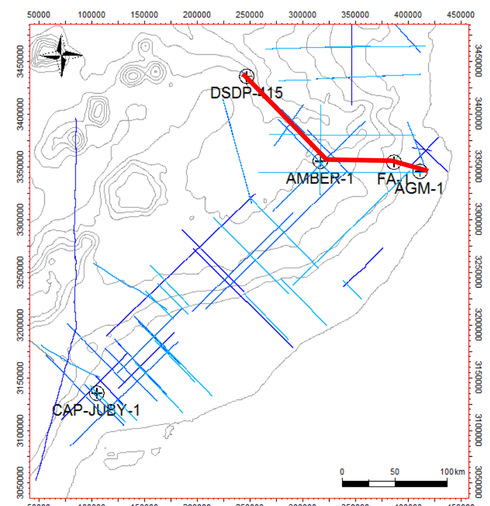


Figure 2.8: Burial history diagrams from Jurassic to Tertiary for 4 wells : A) Agm-1, B) Fa-1, C) Amber-1, and D) DSDP-415 respectively from proximal to distal location.