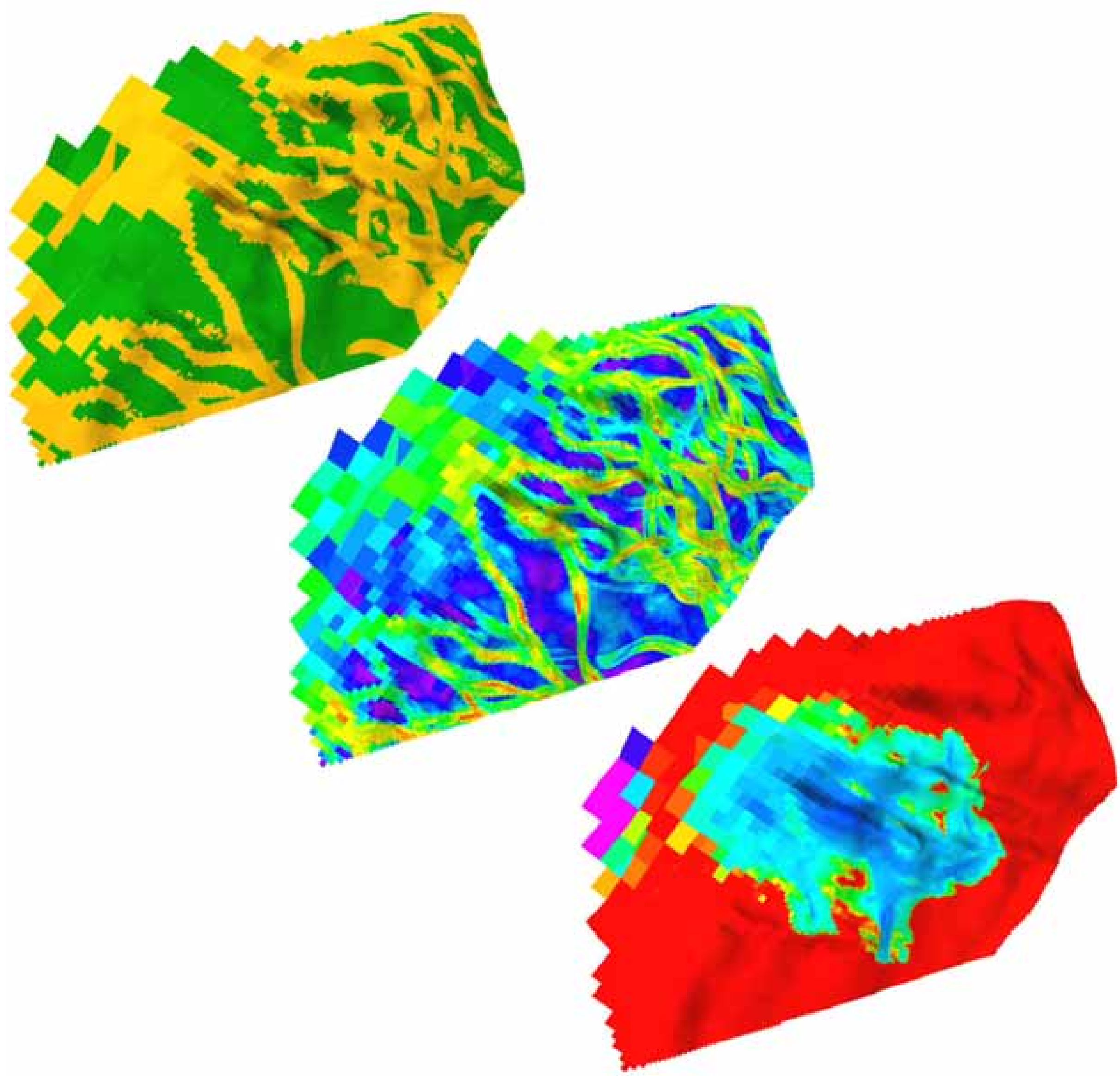
Managing the Interdisciplinary Requirements of 3D Geological Models



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2 CASE STUDY: FLOUNDER FIELD

2.1 Introduction

The Flounder Field in the Gippsland Basin was chosen as the site for a case study for this project. The aim of the case study was to gather the data required for building a 3D geological model. The case study consisted of core interpretation, wireline log interpretation, and 3D seismic interpretation. The core and wireline interpretations were used to construct palaeogeographic maps of the interval of interest. The 3D seismic interpretation provided the structural controls for the 3D models.

The Flounder Field is located approximately 60 km off the Victorian coast in the Gippsland Basin (Figure 2.1). The main hydrocarbon bearing reservoirs are found in the Late Cretaceous intra-Latrobe Group (Figure 2.2). The reservoirs of the Flounder Field are unusual in the Gippsland Basin in that they are located approximately 600 m below the top of the Latrobe Group, rather than at the top of the Latrobe Group (Sloan, 1987) where most Gippsland hydrocarbon accumulations are located. The palaeogeographic maps presented here reflect the trends seen in regional interpretations of the Gippsland basin (for example: Rahmanian et al., 1990; Bernecker and Partridge, 2001), but the interpretation itself has not been tied to any other fields as there are no detailed published descriptions of similar age rocks elsewhere in the basin.

2.2 History

2.2.1 Gippsland Basin Regional History

The development of the Gippsland Basin was initiated by the break-up of Australia and Antarctica during the early Cretaceous. The rift stage that preceded the separation of Antarctica resulted in deposition of volcaniclastic sediments along Australia's southern margins in the Otway, Bass and Gippsland Basins (Willcox et al., 1992; Bryan et al., 1997; Norvick and Smith, 2001). It was during this period that the volcaniclastic sediments of the Strzelecki Group were deposited (Bernecker and Partridge, 2001; Norvick and Smith, 2001) (Figure 2.2). In the Gippsland Basin the rift was bounded by the Lake Wellington, Foster and Cape Everard fault systems (Bernecker et al., 2001) (Figure 2.1). The separation of Australia and Antarctica was represented in the Gippsland Basin by the angular unconformity at the top of the Strzelecki Group (Featherstone et al., 1991; Willcox et al., 1992; O'Sullivan et al., 2000). The rift failed in the Gippsland Basin and the structural highs that separate the Otway, Bass and Gippsland Basin became prominent (O'Sullivan et al., 2000; Norvick and Smith, 2001; Power et al., 2001).

The Strzelecki Group was unconformably overlain by the Latrobe Group (Figure 2.2), which has been subdivided based on intra-formational unconformities that have been identified and correlated with tectonic events (Haskell, 1972; Smith, 1982; Lowry, 1987; Smith, 1988; Lowry and Longley, 1991; Barton et al., 1992; Bernecker and Partridge, 2001). Not all the subdivisions proposed became commonly used in the published literature (for example Smith (1988)). Until the mid 1980s the Latrobe Group encompassed all sediments from the Cenomanian to the Eocene (~100 Ma–33 Ma). The most recent subdivision of the Latrobe Group recognizes four subgroups: the Emperor Subgroup, the Golden Beach Subgroup, the Halibut Subgroup and the Cobia Subgroup (Bernecker and Partridge, 2001).

The Latrobe Group is interpreted to have been deposited during a period of rifting (Emperor and Golden Beach subgroups) (Figure 2.2), followed by basin margin sag (Halibut and Cobia subgroups) (Johnstone et al., 2001). The Emperor Subgroup was deposited in a rift environment as deep lacustrine deposits, whereas the Golden Beach Group was interpreted to have been deposited in a more open fluvial to marine environment (Bernecker and Partridge, 2001). The boundary of the Golden Beach and Halibut subgroups was interpreted to represent the transition from rift to post-rift conditions in the Gippsland Basin area as the opening of the Tasman Sea moved north of the Gippsland Basin (Norvick and Smith, 2001). The Halibut Subgroup sediments were deposited in a marine to fluvial environment. The palaeoshoreline was interpreted to have been orientated in a SW–NE direction, similar to the current shoreline (Rahmanian et al., 1990; Bernecker and Partridge, 2001; Bernecker and Partridge, 2005). During the deposition of the Halibut Subgroup, the opening of the Tasman Sea continued to move northwards. The Tasman Sea ceased spreading at approximately 52–55 Ma (Norvick and Smith, 2001). As the Tasman Sea opened a high-energy coastline developed, the depositional pattern of which was interpreted to have persisted through to the present (Bernecker and Partridge, 2001).

The Halibut Subgroup was truncated by erosional channels in various parts of the Gippsland Basin, including the Flounder Field. The erosion occurred during the *Middle M.diversus* (Johnstone et al., 2001), with the channels being filled during the transgression of the *Upper M.diversus and P. asperopolus* time (Johnstone et al., 2001). These channels (for example, the Tuna–Flounder Channel and Marlin Channel) are variously described as submarine canyons (O'Byrne and Henderson, 1983; Rahmanian et al., 1990; Sloan et al., 1992) or incised valleys formed during subaerial exposure (Partridge, 1976; Brown, 1985; Johnstone et al., 2001; Norvick and Smith, 2001).

The majority of authors (for example: James and Evans, 1971; Brown, 1985; Rahmanian et al., 1990; Baird, 1992; Megallaa, 1993; Johnstone et al., 2001) interpret the Latrobe Group to have been deposited in a period of relative tectonic quiescence. Normal faults (north-west trending), associated with thermal sag, resulting from the spreading of the Tasman Sea developed during this period (Sloan, 1987; Rahmanian et al., 1990; Johnstone et al., 2001; Power et al., 2001). The structural compression that formed the current structures was generally interpreted to have commenced during the Eocene after the erosion the Eocene channels. Based on recent high quality 3D seismic data, Johnstone et al. (2001) brought forward the start of compression to the middle *M. diversus* time period—prior to Eocene channel erosion.

Duff et al. (1991) describe compressional tectonic activity during deposition of the Latrobe Group, as interpreted from sequence stratigraphy & structural analysis of the area around Archer-1 and Anemone-1 (Vic/P20 to southeast of Blackback). They interpret multiple sequence boundaries within the Latrobe Group (in addition to the commonly recognised unconformities associated with the rifting events) that are the result of local tectonic activity rather than global sea-level changes. They conclude that because multiple intra-Latrobe sequence boundaries can be interpreted, there must have been syndepositional compressional tectonic activity throughput the 80–50 Ma period. However Power et al. (2003), in a detailed structural study of the Tuna Field 3D seismic, saw no evidence of compression during the Maastrichtian to Palaeocene.

Deposition in the Gippsland Basin post the Marlin Unconformity was dominated by continued sag and basin deepening. The Cobia Subgroup was overlain by the Seaspray Group of cool-water shelf to basin carbonates (Feary and Loutit, 1998). The Seaspray Group was deposited under conditions of continued basin sag, with intermittent pulses of compression that resulted in the formation of significant canyons (Feary and Loutit, 1998; Holdgate et al., 2000) on the shelf. Rapid carbonate development resulted in the progradation of the shelf to its current position (Rahmanian et al., 1990).

2.2.2 Flounder Field History

The hydrocarobon bearing interval in the Flounder Field is located in the Volador Formation and Roundhead Member of the Halibut Subgroup (Partridge, 2003). At the time of deposition of the Volador Formation and lRoundhead Members, the depositional environment in the Gippsland Basin is interpreted to have been coastal plain to shallow marine (Sloan, 1987; Rahmanian et al., 1990; Baird, 1992; Barton et al., 1992; Moore et al., 1992; Bernecker and Partridge, 2001; Johnstone et al., 2001; Bernecker and Partridge, 2005).

The Flounder Field is located at the crest of a faulted anticline that is oriented in SW–NE direction (Figure 2.3). The faults, which penetrate up to the base of the Flounder Formation (Tuna–Flounder Channel), are aligned in a NW–SE direction (Figure 2.4). The faults are interpreted to be the result of Late Cretaceous to Late Paleocene post rift subsidence associated with the opening of the Tasman Sea`(Sloan, 1987). Growth on downthrown blocks can be seen on 3D seismic (Sloan, 1987; Johnstone et al., 2001).

Compression during the early Eocene is interpreted by Johnstone et al (2001) to have caused the subaerial exposure of the coastal plain, resulting in the incision of the Tuna Flounder Channel (Figure 2.2). A later period of compression during the Lower Oligocene (*N. Asperus*) resulted in the formation of the anticlinal structure of the field today (Sloan, 1987) (Figure 2.2). This event was not associated with erosion in the Flounder field as the area was located in the offshore marine environment at that period (Johnstone et al., 2001).

The distribution of hydrocarbons in the Flounder Field was described by Sloan (1987). The main hydrocarbon bearing zones occur in the T1.1 reservoir in the Roundhead Member (Figure 2.5). The main T1.1 reservoir contains both oil and gas. The reservoir is sealed by a regional shale above the Roundhead Member (Kate Shale) which is interpreted to have been deposited in an offshore marine environment (Sloan, 1987; Bernecker and Partridge, 2001).

2.3 Methodology

Data from core and wireline logs were the basis of a detailed interpretation of the stratigraphy and depositional history of the intra-Latrobe Group in the Flounder Field. The aim of the study was to build up a real data set that could be used as input into 3D geological models. The final product of the field study is a series of palaeofacies maps of the units interpreted.

The interpretation of the wireline data was carried out using Geoquest Geoframe software. Structural models were interpreted from 3D seismic data interpreted using Geoquest IESX software. These were used to define the morphology of the 3D models. The 3D geological models were built in Irap RMS software (see *section 4.3*—modelling methodology).

2.4 Data Used

2.4.1 Wells

The Flounder Field was discovered in 1968 and at the time of data gathering in 2001, the Flounder Field contained 42 wells: 6 exploration wells and 36 developments wells. The development wells are all drilled from one platform near the centre of the field. The degree of penetration of the Latrobe Group is variable, and of the 48 wells in the field, 36 penetrated the zone of interest. Wireline data was provided by ExxonMobil. The logs available in each well can be seen in Figure 2.6.

2.4.2 Cores

Core has been cut in seven wells in the Flounder Field. Approximately 232 m of core covers the interval of interest in six wells (Table 2.1 and Figure 2.7). The best core coverage is in Flounder 6 ST-1 in which the entire section of interest is cored (99 m of core recovered). This well is used as the type well for this project. The cores in Flounder 6, A2, A4, 2 and 3 were chosen as they had the best recovery over the zone of interest (Figure 2.7). The decision not to study Flounder 4 was based on the limited time available, and the poor core recovery in the reservoir zone (Table 2.1 and Figure 2.7).

Well	Core Number	Top (m)	Base (m)	% recovered	Total Cut (m)	Total Recovered (m)	Top (ft)	Base (ft)	Total Cut (ft)	Total Recovered (ft)
Flounder 2	3	2512.2	2530.5	100.0	18.3	18.3	8242	8302	60	60.0
Flounder 2	4	2561.5	2572.2	0.0	10.7	0.0	8404	8439	35	0.0
Flounder 2	5	2572.8	2585.0	57.5	12.2	7.0	8441	8481	40	23.0
Total					**41.2**	**25.3**			**135**	**83.0**
Flounder 3	2	2545.1	2554.8	87.5	9.8	8.5	8350	8382	32	28.0
Flounder 3	3	2554.8	2556.1	81.3	1.2	1.0	8382	8386	4	3.3
Flounder 3	4	2557.3	2565.8	53.6	8.5	4.6	8390	8418	28	15.0
Total					**19.5**	**14.1**			**64**	**46.3**
Flounder 4	1	2500.3	2517.7	100.0	17.4	17.4	8203	8260	57	57.0
Flounder 4	2	2517.7	2535.3	20.7	17.7	3.7	8260	8318	58	12.0
Flounder 4	3	2535.3	2539.6	78.6	4.3	3.3	8318	8332	14	11.0
Flounder 4	4	2539.6	2551.5	71.8	11.9	8.5	8332	8371	39	28.0
Total					**51.2**	**32.9**			**168**	**108**
Flounder 6 ORIGINAL	1	2477.6	2487.2	100.0	9.6	9.6	8129	8160	31	31.5
Flounder 6 ORIGINAL	2	2487.2	2490.7	91.3	3.5	3.2	8160	8172	11	10.5
Flounder 6 ORIGINAL	3	2490.7	2503.8	74.4	13.1	9.8	8172	8215	43	32.0
Flounder 6 ST1	4	2478.0	2487.2	94.2	9.2	8.6	8130	8160	30	28.3
Flounder 6 ST1	5	2487.2	2492.4	69.9	5.2	3.6	8160	8177	17	11.9
Flounder 6 ST1	6	2492.4	2507.0	53.5	14.6	7.8	8177	8225	48	25.7
Flounder 6 ST1	7	2507.0	2520.7	95.0	13.7	13.0	8225	8270	45	42.8
Flounder 6 ST1	8	2520.7	2533.8	93.6	13.1	12.3	8270	8313	43	40.2
Flounder 6 ST1	9	2533.8	2543.0	96.7	9.1	8.8	8313	8343	30	29.0
Flounder 6 ST1	10	2543.0	2557.3	90.1	14.3	12.9	8343	8390	47	42.3
Flounder 6 ST1	11	2557.3	2566.4	100.0	9.2	9.2	8390	8420	30	30.0
Total					**114.6**	**98.8**			**376**	**324.2**

Well	Core Number	Top (m)	Base (m)	% recovered	Total Cut (m)	Total Recovered (m)	Top (ft)	Base (ft)	Total Cut (ft)	Total Recovered (ft)
Flounder A2	1	2560.0	2569.5	92.6	9.5	8.8	8399	8431	31	28.9
Flounder A2	2	2569.5	2573.0	92.6	3.5	3.2	8431	8442	11	10.6
Flounder A2	3	2573.0	2574.0	62.0	1.0	0.6	8442	8445	3	2.0
Flounder A2	4	2578.0	2587.0	57.4	9.0	5.2	8458	8488	30	17.0
Flounder A2	5	2587.0	2596.5	96.9	9.5	9.2	8488	8519	31	30.2
Flounder A2	7	3293.3	3302.5	113.0	9.3	10.4	10805	10836	30	34.3
Total					**41.8**	**37.5**			**137**	**123.0**
Flounder A4	1	2757.0	2766.0	93.3	9.0	8.4	9046	9075	30	27.6
Flounder A4	2	2766.0	2775.8	96.4	9.8	9.5	9075	9107	32	31.0
Flounder A4	3	2775.8	2783.0	88.5	7.2	6.4	9107	9131	24	20.9
Total					**26.0**	**24.2**			**85**	**79.5**

Table 2.1. Details of the cores in the zone of interest. Flounder 6 cores were studied in the most detail, followed by the Flounder A2 and A4 cores. Flounder 2 and 3 cores were examined but and logged in least detail. Flounder 4 core was studied in core photos only. Figure 2.7 shows the location of the cores relative to the reservoir.

2.4.3 Seismic

The 3D seismic data used to define the structure of the Flounder Field models was the 1994 reprocessed survey. The Northern Fields 3D survey (acquired 2001-2002) became available as open file data during the course of this project. Although the quality of the data improved in the Northern Field survey, there was not sufficient improvement in resolution of the zone of interest to justify re-interpretation using the later data. The zone of interest is approximately 80 m thick, approximately 1 wavelength on the seismic.

2.4.4 Reports

Well completion data was gathered from ExxonMobil, and digital copies of the well completion reports for the six exploration wells were obtained from the Victorian Department of Primary Industries. Data in these reports were used to generate time/depth relationships, establish field pressures and aid in the geological interpretation. Palynological interpretation reports were obtained from ExxonMobil. Additional information about palynological interpretation in the area was obtained from palynologist Alan Partridge of Biostrata Pty Ltd.

2.5 Interpretation

2.5.1 Core

The cores were examined over a three day period at the ExxonMobil core store. The core was interpreted with the assistance of Dr Simon Lang and Dr Tobias Payenberg. The focus of the core study was to establish depositional environments in the reservoir interval, and to relate them to the key markers that had been interpreted on the wireline logs prior to the visit. A series of composite logs were produced that combine the core interpretation with the surfaces interpreted at the time. See *Appendix* 1. These logs were the reference used when interpreting depositional environments for the palaeo-deposition maps.

Core shifts were calculated for all cores by tying the logs to identifiable shales, carbonate cement boundaries and sharp lithology changes in the cores (Table 2.2).

Well	Core	% recovery	original top (ft)	*shifted top (ft)*	original base (ft)	*shifted base (ft)*	shift (ft)
Flounder 6	1	100	8129	*8139*	8160	*8170*	+10
Flounder 6	2	90.06	8160	*8170*	8172	*8182*	+10
Flounder 6	3	96.67	8172	*8182*	8215	*8225*	+10
Flounder 6ST1	4	93.6	8130	*8140*	8160	*8170*	+10
Flounder 6ST1	5	95	8160	*8170*	8177	*8187*	+10
Flounder 6ST1	6	53.48	8177	*8187*	8225	*8235*	+10
Flounder 6ST1	7	69.85	8225	*8235*	8270	*8280*	+10
Flounder 6ST1	8	94.17	8270	*8280*	8313	*8323*	+10
Flounder 6ST1	9	74.42	8313	*8323*	8343	*8352*	+10
Flounder 6ST1	10	91.3	8343	*8352*	8390	*8395*	+9
Flounder 6ST1	11	100	8390	*8395*	8420	*8425*	+5
Flounder 3	2	87.5	8350	*83560*	8382	*8392*	+10
Flounder 3	3	81.25	8382	*8392*	8386	*8396*	+10
Flounder 3	4	53.57	8390	*8400*	8418	*8428*	+10
Flounder 2	3	100	8242	8261	8302	8321	+19
Flounder 2	4	*no recovery*					
Flounder 2	5	57.5	8441	*8443*	8481	*8483*	+2

Well	Core	% recovery	original top (m)	*shifted top(m)*	original base(m)	*shifted base(m)*	shift (m)
Flounder A4	1	93.33	2757	*2759.2*	2765.36	*2767.4*	+2.2
Flounder A4	2	96.43	2766	*2767.8*	2775.8	*2777.6*	+1.8
Flounder A4	3	88.47	2775.8	*2777.6*	2782.16	*2783.96*	+1.8
Flounder A2	1	92.63	2560	*2563*	2568.8	*2571.8*	+3
Flounder A2	2	92.57	2569.5	*2572.5*	2572.74	*2575.74*	+3
Flounder A2	3	62	2573	*2576*	2573.62	*2576.62*	+3
Flounder A2	4	57.44	2578	*2581*	2583.17	*2586.17*	+3
Flounder A2	5	96.87	2587	*2590*	2596.28	*2599.28*	+3

Table 2.2. Cores interpreted for this study. This table shows the amount of depth shifting that was required to match the cores with the wireline logs. Core shifts were estimated at a distinctive feature such as a maximum flood or the edge of a carbonate cement band. The measurements given in the table are those that are on the core boxes and official core photos, and as such reflect the units used at the time the cores were cut.

2.5.2 Seismic

The interpretation of the seismic data was carried out in Geoframe's IESX module. The following picks were interpreted on the seismic: top Latrobe, base Tuna-Flounder channel (SB3), TST1 marker and the SB1 marker (Figure 2.4).

The resolution of the seismic is poor at the SB1 marker level and the pick is judged to have poor reliability. For that reason structure maps are based on the higher TST1 marker. Depth conversion was carried out using the formula of TWT = (MD/IV) x 2, where TWT = two way time, MD = measured depth and IV = interval velocity. The interval velocity at the wellbore was calculated and contoured for the field. This IV map was then multiplied with the TWT map to produce a depth converted surface. The isopach between the tst-1 marker and the RU.4 marker was calculated at the wellbore, contoured and applied to the depth converted TST1 surface. As can be seen in Figure 2.4, the TST1 marker is approximately parallel to the SB1 surface.

Although faults were interpreted in the Flounder Field, they were not exported out of Geoframe. The faults were not created within RMS as the impact of post-depositional features is not the focus of the project. The influence of faults on production, and how they are upscaled, would add an extra layer of complexity to the project and potentially mask the influence of depositional architecture on the reservoir simulation results (Bailey et al., 2002; Ainsworth, 2005; Ainsworth, 2006).

2.5.3 Wells

Interpretation of wireline logs was carried out using Geoframe Wellpix. A series of strike and dip sections were created in order to correlate all the wells. A total of 21 surfaces were interpreted in the upper Roundhead Member to upper Volador Formation interval (Figure 2.8). This includes two sequence boundaries and 19 flooding surfaces. Key markers were also interpreted for tying the seismic to the well data. These were the top Latrobe, base Tuna-Flounder channel (SB3), TST-1, and SB1 (Figure 2.4).

All gamma logs in the Flounder Field have been adjusted so that the cleanest sand in the upper and lower Roundhead Member has a value of approximately 20gAPI[2] units. The normalization was achieved within Geoframe by bulk shifting the entire gamma curve, but is intended for use over the upper and lower Roundhead Member and upper Volador Formation

[2] gAPI = American Petroleum Institute gamma ray units

only. The normalization allowed automated lithofacies interpretation to be carried out. The lithofacies interpretation of the wireline logs was carried out in the Geoframe module LithoQuickLook. This process consisted of applying baseline cut-offs to the gamma and sonic logs to establish basic lithofacies. Lithofacies interpreted were sand, shaley-sand, sandy-shale, shale, coal, carbonate cement. These lithofacies, in combination with log signatures and palaeo-facies maps were used to interpret depositional facies away from the core data. Depositional facies associations interpreted were fluvial channels, overbank, restricted marine, barrier bar, tidal inlet, estuarine, upper-middle shoreface, offshore-transition and transgressive lag.

2.6 Stratigraphic Interpretation

2.6.1 Previous

The section of interest is defined by Bernecker and Partridge (2001) as the Roundhead Member of the Halibut Subgroup and the upper part of the Volador Formation. The Roundhead Member has also been described by Sloan (1987) as the T1.1 reservoir sand (Figure 2.5). Rahmanian et al (1990) described two sequence boundaries in the intra-Latrobe section. They were named the 67MA and 68MA events. As it is unlikely that these dates were obtained from biostratigraphic data in the Flounder Field their origin is unclear; but they may be related to third order cycles extrapolated from the global coastal onlap curves of Haq et al. (1988). Partridge (2003) includes the coastal onlap curves in a stratigraphic column for the Gippsland Basins. Figure 2.9 shows two relative sea level falls close to the 67MA and 68MA sequence boundaries interpreted by Rahmanian et al (1990). If the relative sea level curve is shifted downwards slightly, these two falls match precisely the relative sea level falls seen in the core. However, the curve will no longer match events higher or lower in the section. Miall (1991; 1992) noted that the third order events on the Haq curves are below the resolution of biostratigraphic data and can be interpreted to fit almost any dataset.

The depositional environments in the Flounder Field have been interpreted as marine to fluvial (Sloan, 1987; Rahmanian et al., 1990; Bernecker and Partridge, 2001; Bernecker and Partridge, 2005). Rahmanian et al. (1990) provides a detailed analysis of the depositional environments during the deposition of the Latrobe Group. Their interpretation is based on an extensive review of the core available, at that time, in the Esso permit areas in the Gippsland Basin. This study focuses in on a small interval within the intra-Latrobe and provides a more detailed depositional interpretation of the area than has been previously published.

2.6.2 This Study

The Roundhead Member, previously described as one unit (Sloan, 1987; Bernecker and Partridge, 2001) is here divided into two units: a lower unit consisting of sandy transgressive shoreface facies and an upper unit consisting of lowstand incised valley fill—predominantly of fluvial to estuarine sediments (Figure 2.7).

The upper Volador Formation (VU units), lower Roundhead Member and the upper Roundhead Member (RL and RU units respectively) have each been subdivided into units bounded by flooding surfaces (Figure 2.7). The units were interpreted in all wells that penetrated them. The VU.0 marker (base of the VU.1 unit) is the lowest marker that could be reliably interpreted with the available penetrations. The core interpretation in Flounder 6 ST1 below the VU.0 marker is used to strengthen the depositional environment interpretation of the upper Volador Formation.

2.7 Core Interpretation – This Study

Cores from five wells (Flounder 2, 3, 6, A2, A4) were examined to determine the depositional environments present in the intra-Latrobe Formation in the Flounder Field (Table 2.2). Core photos from another well, Flounder 4, were also studied. One well, Flounder 6 ST1, was cored continuously through the section of interest, and is the key well for this study (Figure 2.5). Flounder 6 was drilled to the middle of the lower Roundhead Member and then sidetracked. Both the original well and the sidetrack are cored. The distance between the original borehole and the sidetrack is unknown, but presumed to be very close (pers, comm. M. Hordern, ExxonMobil,). This is borne out by the cores, which are very similar. Cores 4–11, which were cut in the sidetrack, provide near complete coverage over the zone of interest. Cores 1, 2 & 3 were cut in the original well and cover approximately the same interval as cores 4, 5 & 6 (Figure 2.5).

2.7.1 Facies Associations

A total of thirteen facies associations (FA1 to FA13) were interpreted in the cores. These facies associations are based on bedding style, bioturbation and lithology. They are used to interpret depositional environments and some occur in more than one stratigraphic interval.

Facies Association 1—Tide-Influenced Lagoon

Description. A carbonaceous shale interbedded with thin sand beds (0.01–0.03 m), shaly sandstone and fine-grained, clean sandstone. Flaser bedding is common. Also present is a 0.15 m bed containing several mollusc (oyster?) shells in a muddy matrix. The clean sandstone beds are 0.5–0.7 m thick and have a sharp base and top and are intensely bioturbated—no bedding planes remain. (Figure 2.10, Figure 2.12, Figure 2.13). This facies association is cored in Flounder 6, core 9, 10 and 11.

Interpretation. The dominance of shale indicates a low energy environment, below fair-weather wave base, while the flaser bedding indicates a tidal influence. Oyster beds are common in Cretaceous lagoonal deposits (Reinson, 1984). The sharp-based sands are interpreted as washover deposits. Deposition is interpreted to have occurred in a lagoon with tidal influence.

Facies Association 2—Restricted Lagoon

Description. Predominantly carbonaceous laminated shale beds 2–3 m thick with occasional very thin layers of sand and occasional individual grains (Figure 2.13). It is generally lacking bioturbation, however there are several very large sand sand-filled burrows within the carbonaceous layer in Flounder A4 (Figure 2.14). These burrows are sand-filled and contain poorly sorted fine to coarse sand grains. The shale is deformed by the burrows. This facies association is cored in Flounder 6, core 3, 9 and 10 and Flounder A4 core 1.

Interpretation. The carbonaceous material and sparse bioturbation indicate a low energy environment that was not hospitable to burrowing organisms. The presence of thin sand layers suggests proximity to a sediment source, possibly a restricted lagoon environment. The sand-filled burrows seen in Flounder A4 may have originated in the overlying highly bioturbated sandstone.

Facies Association 3—Barrier Shoreface

Description. A 3.5 m thick fine to medium-grained, bioturbated sand (including *Ophiomorpha*) with some remnant cross-beds at its base (Figure 2.15). This facies association is cored in Flounder 6, core 9.

Interpretation. The presence of *Ophiomorpha*, is typical of relatively high energy, shallow marine environments (shoreface) (McEachern et al., 2005). The position of this facies association between lagoon deposits (Facies Association 1—FA1) and open marine deposits (FA4) indicates that the shoreface was most likely to be part of a barrier-shoreface system.

Facies Association 4—Offshore Transition

Description. A mixture of interbedded shale, shaly sandstone and a fine-grained, upward-cleaning clean sandstone (1.5 m thick). Hummocky cross-stratification (HCS) is common in the shaly sandstone, while planar cross-beds can be identified in the clean sandstone. Bioturbation is common in the shaly sandstone and the sandstone, and increases with increasing sand content. There is a variety of burrow sizes, shapes and orientations. No mud drapes or oyster shells were identified. (Figure 2.16). Cored in Flounder 6, core 8; Flounder 4, core 3; Flounder A2, core 5 and Flounder A4 core 7.

Interpretation. The absence of flaser bedding and oyster shells differentiates this facies association from FA1. The presence of HCS is indicative of deposition above storm wave base, and the lack of cross-bedding suggests below fair-weather wave base (Elliott, 1986b). Hence the shaley sandstone is interpreted to have been deposited in the offshore-transition zone. The clean, planar-bedded sandstone suggests a relative sea level drop and preservation of a portion of middle shoreface.

Facies Association 5—Lower – Middle Shoreface

Description. Predominantly a fine-grained, cemented, bioturbated sandstone 2–6 m thick. *Ophiomorpha* are the most common trace fossils. No bedding structures are noted. (Figure 2.16 and Figure 2.17). Cored in Flounder 6, Core 8; Flounder A4, cores 1 and 3; Flounder 4, cores 3 and 4.

Interpretation. The *Ophiomorpha* trace fossils are commonly associated with a relatively high energy environment of the shoreface environment (McEachern et al., 2005). The presence of numerous mud-lined burrows indicates that the energy level was insufficient for physical reworking to obliterate all burrows as is likely in the upper shoreface environment. Deposition in a lower to middle shoreface depositional environment is interpreted.

Facies Association 6—Middle – Upper Shoreface

Description. A 2–10+ m thick, medium to coarse-grained, cemented sandstone with occasional bioturbation. No bedding structures are visible in Flounder 6. It is interbedded with 0.3 m layers of fine-grained sandstone that contains wispy layers of carbonaceous material (often bioturbated) (Figure 2.17 and Figure 2.18). In Flounder 6 the thick sandstone appears to be heavily bioturbated, though only a few vertical burrows are identifiable. In Flounder A2 and Flounder 2 it appears to be unbioturbated, with an occasional low angle bedding plane. Cored in Flounder 6, core 7; Flounder A2, core 5, Flounder 2, core 5 and Flounder 4, core 3.

Interpretation. The decrease in bioturbation relative to that seen in FA5 indicates deposition in a higher energy environment such as the middle to upper shoreface. The layers of fine-grained, bioturbated sandstone may represent a brief rise in relative sea level and associated increase in mud content. Some of these layers correspond to spikes on the gamma log that can be correlated across the field (Figure 2.18).

Facies Association 7—Fluvial Channel

Description. A fining-upward, coarse to very coarse-grained, sandstone 12 m thick. This sandstone is not bioturbated and contains low-angle bedding planes and occasional climbing ripples. A subtle erosion surface at the base of the facies is present (Figure 2.19 and Figure 2.20). The top of the facies is marked by a decrease in grainsize and the presence of occasional mud-lined burrows. Cored in Flounder A4, cores 2 and 3.

Interpretation. The lack of bioturbation in this facies could be indicative of deposition in the upper shoreface or a fluvial environment. The presence of climbing ripples indicates there was abundant suspended sediment, rapid deposition and bottom flow (Tucker, 1982; Edwards, 1986). The absence of bioturbation may be due to either rapid sedimentation or a change in salinity rendering the interval uninhabitable by the marine organisms that inhabited FA5. As this facies generally fines-upward and has an erosive base, deposition in a fluvial channel is interpreted.

Facies Association 8—Low Sinuosity Fluvial Channel

Description. Predominantly a medium to coarse sandstone that shows little evidence of bioturbation with occasional thin shale layers. Bedding features include pebble lags and some subtle low angle bedding. The sandstone is 8 m thick in Flounder 6, and has poor recovery in other wells. The sandstone has an abrupt, apparently erosive contact with the underlying shale (Figure 2.21). Found in Flounder 6, cores 3, 5, 6; Flounder A2, cores 3,4 and 5; Flounder 3, cores 3 and 4; Flounder 4, core 2.

Interpretation. The sudden, erosive, change from marine sediments (FA 4 in Flounder 6) to coarse, clean unbioturbated sandstone indicates a significant shift in depositional environment. The facies association is widespread across the field. Stacked fluvial channels deposited in a low sinuosity regime are interpreted as there is no evidence of point bar or overbank deposits.

Facies Association 9—Estuarine

Description. Primarily clean, fine to medium-grained sandstone beds 0.02–0.1 m thick, interbedded with 0.02–0.03 m layers of fine grained sandstone with bioturbated mud-drapes

(Figure 2.22). Bioturbation, although common, appears to be of low diversity. Also present are occasional 0.2 m beds of upward-coarsening fine to medium grained, unbioturbated sandstone that contain low angle bedding. Found in Flounder 6 cores 1, 2 and 4.

Interpretation. The presence of bioturbation and the more numerous shale drapes indicate a shift away from a fluvial environment to one of variable energy. The low diversity of burrows suggests a brackish environment, such as an estuarine system. A bayhead delta in an estuarine environment is interpreted as the source of the upward coarsening layers.

Facies Association 10—Estuarine – Central Basin

Description. Predominantly interbedded fine-grained silty-sand and shale packages which are 0.3–0.6 m thick. While most of the silty-sand beds are extensively bioturbated, some are not and planar and low angle cross-bedding is clearly visible. Where burrows are preserved, they are often circular in cross section. Found in Flounder 6, cores 1, 4; Flounder A2 core 2; Flounder 3 core 2 and Flounder 4 core 1.

Interpretation. The bioturbation has a low diversity, suggesting stressful conditions for burrowing organisms. The absence of mud drapes indicates a location with a quiet, consistent energy regime (Allen, 1968), such as the central basin.

Facies Association 11—Transgressive Lag

Description. An upward-coarsening coarse to very coarse, poorly sorted sandstone approximately 1 m thick (Figure 2.25). It contains occasional round, mud-lined burrows. No bedding structures are visible. Found in Flounder 6, core 4.

Interpretation. This is an erosive unit between estuarine deposits (FA10) and overlying open marine sediments (FA11). It is interpreted to be the remnant of the shoreface that transgressed landward as sea level rose.

Facies Association 12—Offshore Transition

Description. Interbedded fine sand and shale, which is extensively bioturbated, though some sandstone beds remain undisturbed and contain planar bedding. The bioturbated sandstone layers are 0.05–0.4 m thick, with the unbioturbated beds being 0.1–0.4 m thick. Bioturbation is diverse. Found in Flounder 6, core 1 and 4, Flounder A2, core 1; Flounder 3, core 2 and Flounder 4, core 1.

Interpretation. The extensive, diverse bioturbation indicates an open marine environment. The planar-bedded sandstone layers are interpreted as storm deposits, which were interspersed with quiet periods when biogenic activity is intense. The presence of storm deposits indicates that deposition occurred above storm wave base in the offshore transition zone.

Facies Association 13—Offshore

Description. A silty-sand that grades into grey shale, 13+ m thick. There are a variety of well preserved mud-lined burrows in silty-sand at the base of the facies. There are no visible bedding planes in the shale—which may be extensively bioturbated. Found in Flounder 2, core 3.

Interpretation. The lack of preserved sand beds indicates deposition occurred below storm wave-base, in an environment hospitable to organic activity, such as an offshore marine setting.

2.7.2 Facies Association by Formation

The distribution of the facies associations is closely aligned to the three formations interpreted (Table 2.3 and Figure 2.10). Facies associations 1 to 4 are found within the upper Volador Formation. The upper Volador Formation is interpreted to have been deposited in a barrier-shoreface system that transgressed across the field. The preservation of the barrier and the lagoon deposits indicates that the sea level rose relatively quickly, drowning the barrier, rather than eroding it, as would be the case in a slow sea level rise (Davis and Clifton, 1987).

	Facies Association	Lithology	Depositional Environment
upper Roundhead Member	12, 13	bioturbated sand and shale	offshore
	11	coarsening-upward sand	transgressive lag
	9,10	bioturbated sandy shale	estuarine, central basin, bayhead delta
	8	coarse sand, planar bedding, fining-upward	fluvial
lower Roundhead Member	4	bioturbated sandy shale	offshore transition
	2	carbonaceous shale	lagoon
	7	fining-upward sand, no bioturbation	fluvial
	5 & 6	bioturbated sand	upper–middle–lower shoreface
upper Volador Formation	5	bioturbated sand	lower–middle shoreface
	4	HCS, sand and shale, bioturbated	offshore transition
	3	bioturbated sand	barrier shoreface
	1, 2	flaser bedding, oysters, bioturbated, carbonaceous shale	Tide-dominated lagoon, restricted lagoon

Table 2.3. Facies associations and their depositional environments.

Facies Associations 5 to 7 are found in the lower Roundhead Member. This indicates that the lower Roundhead Member was deposited in a shoreface environment. FA4 is also found in the lower Roundhead Member during periods of marine transgression, in particular RL.3. It should be noted that although the top of each unit interpreted is associated with a spike on the gamma log, this does not always correspond in the core to a shale layer (Figure 2.18). FA1 and FA2 are also found near the top of the lower Roundhead Member, indicating a return to a barrier shoreface depositional system in the RL.7 and RL.8 units. Facies Associations 8 to 13 are found in the upper Roundhead Member. FA8 is found in the RU.1, RU.2 and RU.3 units, indicating widespread fluvial deposition in the basal units of the upper Roundhead Member. Although the RU.2 unit in Flounder 6 appears to be shale layer on the wireline logs, there is no corresponding layer of shale approximately 0.6 m thick in the core. The high gamma response is most likely to be caused by carbonaceous layers within the sandstone. In Flounder 6 the fluvial deposits of RU.1 are overlain by estuarine deposits. The lack of significant shale breaks in the lower part of the upper Roundhead Member unit indicates a low accommodation to sediment supply ratio during the valley fill phase. The blocky log signature, planar bedding, in combination with the absence of any channel abandonment or overbank deposits in the core, is interpreted as indicative of a low sinuosity fluvial deposition on the RU.1 unit (Miall, 1977; Cant, 1978; Bridge, 1985; Davies et al., 1993).

The core over the RU.2 unit in Flounder 6 shows a change from clean sandstone, to bioturbated sandy shale (Figure 2.22). This is interpreted as a shift to estuarine conditions as the incised valley is transgressed during relative sea level rise. At a similar stratigraphic level in Flounder A2 and Flounder 3 there is no indication of estuarine conditions at this time. This suggests that Flounder 6St1 was out of the main depositional fairway, and that fluvial deposition was still occurring in the area. The RU.3 unit in Flounder 6 is also interpreted as estuarine, whilst there is no sign of estuarine conditions in the other cores at this level.

The end of fluvial influence across the field seems to have taken place at the base of the RU.4 unit. In all cores studied, there is a switch to fine-grained, bioturbated sand and or sandy shale. In Flounder 6ST1, this interval (FA10) is interpreted as central basin deposits due to the lack of clean sands Interbedded with shales, suggesting a more distal location from the delta (Figure 2.22). The bioturbation patterns in Flounder 3 and 4 are also considered to be more characteristic of a restricted environment than an open marine one. The Interbedded sand and shale packages are interpreted as bayhead delta deposits (Figure 2.23).

In Flounder A2 there appears to have been a rapid switch to shoreface conditions at the base of the RU.4 unit (Figure 2.24). There does not appear to be any tidal or estuarine sediment at this location. It is interpreted that at this location the transgressive shoreface eroded the underlying estuarine deposits during the final marine transgression across the field. The coarsening-upward sand at the top of the RU.4 unit in Flounder 6 is interpreted as a transgressive lag associated with the transgressive surface of erosion (Figure 2.25). The preservation of only a lag indicates that the relative sea level rise was relatively slow. Above the transgressive lag, the section slowly deepens, but remains above storm wave base in the cored intervals in Flounder 6 and A2. The sharp-based sand in Flounder A2 is interpreted to be a storm deposit (Figure 2.26).

The core interpretation in Flounder 6 bears a close resemblance to the fill patterns for incised valleys described by Dalrymple et al. (1994) and Zaitlin et al. (1994). The progression from fluvial sediments at the base of the channel through to estuarine sands, offshore shale capped by a transgressive bar is typical of the seaward portion of an incised valley system (Figure 2.27).

2.8 Palaeogeography

The depositional environments interpreted in core were extended away from the cored intervals through wireline log interpretation of the wells with no core. Although lower–middle and middle–upper shoreface were interpreted in the facies associations, it is not possible to make such distinctions on the wireline log data alone. Thus all palaeogeography maps show a shoreface facies that incorporates lower, middle and upper shoreface sediments. Similarly, although two facies associations are interpreted as separate lagoon deposits they have been mapped as one, as in the modelling process they will be merged into one facies.

2.8.1.1 Upper Volador Formation

The barrier-shoreface system interpreted in the Flounder 6ST1 core is seen on the log signature plot to have a palaeo-shoreline oriented northeast–southwest through the centre of the field, bounded landward and seaward by lagoonal and offshore marine shales (Figure 2.28 and Figure 2.29). A relative sea level rise during the VU.3 unit resulted in a marine transgression that deposited shale across the field (Figure 2.30). The VU.4 and VU.5 units are also interpreted to have been deposited in a barrier shoreface setting, though there are no cases of a shale-rich unit landwards of a sandy section (Figure 2.31 and Figure 2.32). There are numerous fining-upward or blocky log signatures adjacent to coarsening-upward log signatures that are interpreted as tidal inlet deposits. The relative sea level appears to be stable during the VU.4 and VU.5 periods as there is no significant difference in the position of shoreline between the two units.

2.8.1.2 Lower Roundhead Member

The lowermost sequence boundary, SB1, visible in the core, is indicated by an abrupt shift from lower/middle shoreface sediments to upper shoreface sediments. Cross sections (Figure 2.7) and the palaeofacies maps (Figure 2.29) show that the uppermost unit of the upper Volador Member is eroded in the centre of the field in a northwest–southeast orientation. The overlying unit, RL.1, onlaps the sequence boundary in a similar orientation, infilling the incised valley with up to six metres of middle shoreface sediments (Figure 2.33 and Figure 2.34). The palaeofacies maps indicate that during RL.1–RL.3 the shoreface transgressed over the field, depositing a maximum flooding surface at the top of the RL.3 unit (Figure 2.35). The RL.3 unit is interpreted to contain upper delta plain or coastal plain deposits in the north of the field. The shoreface then aggraded or transgressed slowly. This resulted in a wider strandplain and a greater juxtaposition of fluvial channel sediments and shoreface facies in the RL.4–RL.6 units than in the RL.3 unit (Figure 2.33, Figure 2.35, Figure 2.36, Figure 2.37 and Figure 2.38).

In Flounder A4, the fluvial channel sand (Figure 2.19) is adjacent to wells with a high gamma log signature—interpreted as overbank or interdistributary bay deposits (Figure 2.35). Other fluvial deposits in the lower Roundhead Member are interpreted from their blocky or fining-upward log signature. Where core is available these log signatures usually correspond to the coarse sandstones that have no to minor bioturbation (FA 7, Figure 2.19). Where they are adjacent to coarsening-upward log signatures (interpreted as middle-upper shoreface) they are interpreted as fluvial channels intersecting a shoreface. No estuarine or interdistributary bay deposits are interpreted in the cores. This suggests that the preserved fluvial channels are the result of a river flood event that incised the shoreface sediments, and that in normal, quiet conditions the fluvial sediments may be rapidly reworked into the shoreface facies. The lower Roundhead RL.1 to RL.6 units have not been interpreted as a barrier-shoreface system with preserved tidal inlets, because unlike the upper Volador Formation, there are no log signatures that appear to represent lagoon or offshore facies in the lower Roundhead Member. The width of the belt of clean, coarsening-upward sand (approximately 4 km) is also much wider than that seen in the upper Volador Formation and in the overlying RL.7 and RL.8 units.

The juxtaposition of fluvial channels and shoreface deposits can be seen in aerial images of many modern wave dominated deltas (see *section 3.2* for discussion of shoreface facies). In the absence of definitive indicators that the RL.3 to RL.6 units were deposited in either a storm-dominated delta, a coast with individual channels or a barrier shoreface system, it has been interpreted as a shoreface with isolated channel belts approximately perpendicular the shoreface. The distribution of channel belts along the coast is more frequent than is seen in modern environments as each unit represents a significant period of time, during which multiple channels may have developed.

The thickness of these single storey channel belts ranges from 2–6.5 metres (average 4 m). Single story channels this small are likely to have narrow belt widths. As an indicator of potential channel width, the channel thicknesses were plotted on a width to channel belt thickness plot taken from Fielding and Crane (1987). This indicated that in a fluvial setting, such channels would probably be associated with channel belts approximately 40–350 m (average 150 m) wide (Figure 2.39). The width:thickness ratio of distributary channels on deltas tends to be smaller than those upstream due to the avulsive behavior of channels on the delta plain (Elliott, 1986a).

The restricted marine sediments seen in Flounder A4 near the top of the lower Roundhead Member (RL.7) suggests a return to a barrier shoreface coast during the late stages of the lower Roundhead Member. This interval correlates to the offshore marine shale seen in the core in Flounder 6ST1, indicating that the barrier shoreface was approximately one kilometre wide in this area (Figure 2.33 and Figure 2.40).

Palaeofacies maps of the Gippsland Basin (Rahmanian et al., 1989; Rahmanian et al., 1990; Johnstone et al., 2001; Bernecker and Partridge, 2005) show that the palaeoshoreline during deposition of the Latrobe Group siliciclastics was in the order of 100–150 km long and the shoreface 5–20 km wide. The palaeofacies maps of the Flounder field indicate that the shoreface sediments covered the entire field in the RL.5 & RL.6 units–giving the strandplain a width of at least 3.5 km, and a length of at least 7 km. A seismic variance slice of the interval below the Kate Shale (the upper Roundhead Member) to the northeast of the Flounder Field shows linear features aligned in a northeast-southwest direction (Figure 2.41).

These are interpreted as possible shoreline deposits (pers. com. J. Sayers, ASP, 2008). The source of the sediment feeding the strandplain is not clear from the field data. The relatively small size of the field means that the sediment source could be an adjacent wave dominated delta whose fluvial facies are either not penetrated in the field or were rapidly reworked into the strandplain. Other possible sources for sediment supply are longshore drift (for example: Boyd et al., 2004), or reworking of lowstand deposits (for example: Bird, 1973; Bird, 1993).

2.8.1.3 Upper Roundhead Member

The lower Roundhead Member is truncated by Sequence Boundary 2 (SB2) across the field. Correlation of 38 wells indicates that SB2 is associated with an incised valley, as defined by Zaitlin et al. (1994), that is filled by up to 20 metres of channel fill (Figure 2.42 and Figure 2.43). The erosion associated with SB2 can be seen on the palaeofacies maps of the lower Roundhead Member down to RL.5 (Figure 2.33). The lowstand fluvial fill covered the entire field during RU.1. The orientation of the incised valley is taken from the orientation of the erosion of the underlying units. The landward boundary of the erosion appears to be oriented in a NE–SW direction (Figure 2.40). The width of the incised valley is unknown as it is outside the confines of the field. The regional seismic variance slice of the interval below the Kate Shale (upper Roundhead Member) indicates that there were shorelines present to the northeast at this time, but not over the Flounder Field (Figure 2.41). The maximum amount of incision interpreted in the wells is 20 metres, which is below the resolution of the Flounder 3D seismic at this depth (pers. com. J. Sayers, ASP, 2008).

The RU.1 zone is present across the field, but varying thickness suggests that there were multiple channels or channel switching occurred. The isopach map of the unit shows one main incised channel belt, separated from a second lesser incision by a relative high, on which channel margin deposits accumulated (Figure 2.44). Away from the high, the log signature consists of blocky, stacked packages. The stacked channels are indicative of an environment where sediment supply exceeds accommodation space. The log signature plot indicates that the channel fill is made up of stacked channel bars, rather than a single deep channel. The lack of overbank deposits indicates a high sediment load, a low accommodation space, a high discharge rate or high valley slope (Bridge, 2006). The predominance of fluvial fill in the incised valley is indicative that sediment supply kept pace with a slow relative rise in sea level (i.e. aggradation). As most of the valley fill was deposited below the maximum flooding surface, the sediments belong to the late lowstand to early transgressive systems tract (Willis, 1997).

The RU.2 unit has been interpreted as being deposited in an estuarine environment. The increase in shale content of the sand and distribution of shale and sand lithofacies indicate that this unit was not deposited in the same high energy, high sediment supply regime as the RU.1 unit. Although there is little core data over this interval, the log signature plots suggest that central basin fill and bayhead delta facies may have been present (Figure 2.45), typical of the model of transgressive incised valley fill proposed by Zaitlin et al. (1994). The RU.2 is interpreted to have been eroded in places by the overlying RU.3 unit. The estuary is depicted as a wave-dominated estuary as this is in keeping with the overall wave-energy profile of the Latrobe Group. This study and others interpret wave-dominated environments such as strandplains and barrier island systems throughout the Latrobe Group (Sloan, 1987; Rahmanian et al., 1990; Bernecker and Partridge, 2001; Bernecker and Partridge, 2005).

The RU.3 unit is sandier than the underlying RU.2 unit, indicating either a slight lowering of relative sea level at the base of the unit or an increase in sediment supply. Bioturbation in the core in Flounder 6 indicates that estuarine conditions still prevailed in the south of the field. The coarse, unbioturbated sandstone in Flounder 3 at this level indicates that fluvial conditions were present in the north of the field (Figure 2.46). The RU.4 unit marks a shift to estuarine conditions across the field (Figure 2.47). In the lower part of the RU.4 a bayhead delta is mapped as the cores in Flounder 3 and 4 indicate pulses of sand were entering the estuary. The transgression continued, leaving a transgressive lag in the centre of the field in RU.4 (Figure 2.48) which is overlain by open marine sediments.

2.9 Sequence Stratigraphy

Two partial and one complete sequence are interpreted in the zone of interest (Table 2.4 and Figure 2.49). The overall succession shows a back-stepping palaeo-coastline dominated by overall marine transgression, but interrupted by periods of relative sea level fall, with associated erosion. Sequence Boundary 1 is an abrupt shift from lower shoreface to upper shoreface facies (with some erosion) while Sequence Boundary 2 is marked by the development of an incised valley system, normal to the underlying shoreline, which was filled with coarse-grained fluvial sediments.

Lowstand systems tract deposits (LST) are interpreted at the base of the lower Roundhead Member (RL.1, RL.2 and RL.3) and the upper Roundhead Member (RU.1) (Figure 2.49). Transgressive systems tracts (TST) are interpreted in the upper Volador Formation (VU.1, VU.2 and VU.3), the lower Roundhead Member (RL. 4, RL.5 and RL.6) and the upper Roundhead Member (RU.2, RU.3 and RU.4). The change from LST to TST is interpreted principally from wireline logs. Several core intervals hint at the possibility of erosion at the LST/TST boundaries in Flounder 6ST1, but there is nothing definitive. In the lower Roundhead Member the top of the RL.3 unit marks the point at which the late lowstand deposits completely cover the field (Figure 2.31). In the upper Roundhead Member the top of the RU.1 unit marks the point at which the incised valley fill switches from fluvial to estuarine in Flounder 6. Using the definition of sequence stratigraphy of incised valleys described by Zaitlin et al. (1994) and Boyd et al. (2006) this point marks the transition from LST to TST. The transgressive lag seen in RU.4 higher in the section is most likely to represent the wave-ravinement surface created as an open marine system transgresses the estuary (Zaitlin et al., 1994).

		Unit	Systems Tract	Depositional environment
upper Roundhead Member		RU.4	TST	Estuarine
upper Roundhead Member		RU.3	TST	Estuarine/fluvial
upper Roundhead Member	TSE2	RU.2	TST	Estuarine/fluvial
upper Roundhead Member	SB2	RU.1	LST	Fluvial
lower Roundhead Member		RL.9	HST	Barrier
lower Roundhead Member		RL.8	HST	Barrier
lower Roundhead Member	MFS1	RL.7	HST	Barrier
lower Roundhead Member		RL.6	TST	Shoreface
lower Roundhead Member		RL.5	TST	Shoreface
lower Roundhead Member	TSE1	RL.4	TST	Shoreface
lower Roundhead Member		RL.3	LST	Shoreface
lower Roundhead Member		RL.2	LST	Shoreface
lower Roundhead Member	SB1	RL.1	LST	Shoreface
upper Volador Formation		VU.5	HST	Barrier
upper Volador Formation	MFS0	VU.4	HST	Barrier
upper Volador Formation		VU.3	TST	Open marine
upper Volador Formation		VU.2	TST	Barrier
upper Volador Formation		VU.1	TST	Barrier

Table 2.4. Systems tracts in the Flounder Field. The blue dashed lines represent a maximum flooding surface, the green dashed lines represent a transgressive surface of erosion and the red zig zag represents a sequence boundary.

Highstand systems tracts are interpreted in the upper Volador (VU.4 and VU.5 units) and lower Roundhead Member (RL.7 and RL.8). Highstand deposits are also highly likely to be present above the zone of interest in the Kate Shale (Figure 2.9).

The majority of units interpreted in this study are bounded by regional flooding events. The unit boundaries indicate points at which significant changes in depositional environment took place—most likely in response to changing accommodation to sediment supply ratios. In the lower Roundhead Member the units can be referred to as parasequences—as defined by Van Wagoner et al. (1990). It is less clear whether the units interpreted in the Upper Volador

Formation represent parasequences. The high shale content in the upper Volador makes it difficult to interpret individual coarsening-upward packages with any certainty, and only the most distinctive flooding surfaces have been correlated. The units interpreted in the upper Roundhead Member do not represent parasequences as they are related to relative sea level falls as well as rises (Kamola and Van Wagoner, 1995; Posamentier and Allen, 1999).

2.10 Figures – Flounder Field

NOTE:
This figure is included on page 41 of the print copy of the thesis held in the University of Adelaide Library.

Figure 2.1. Gippsland Basin, structural setting. Modified from Bernecker and Partridge (2001).

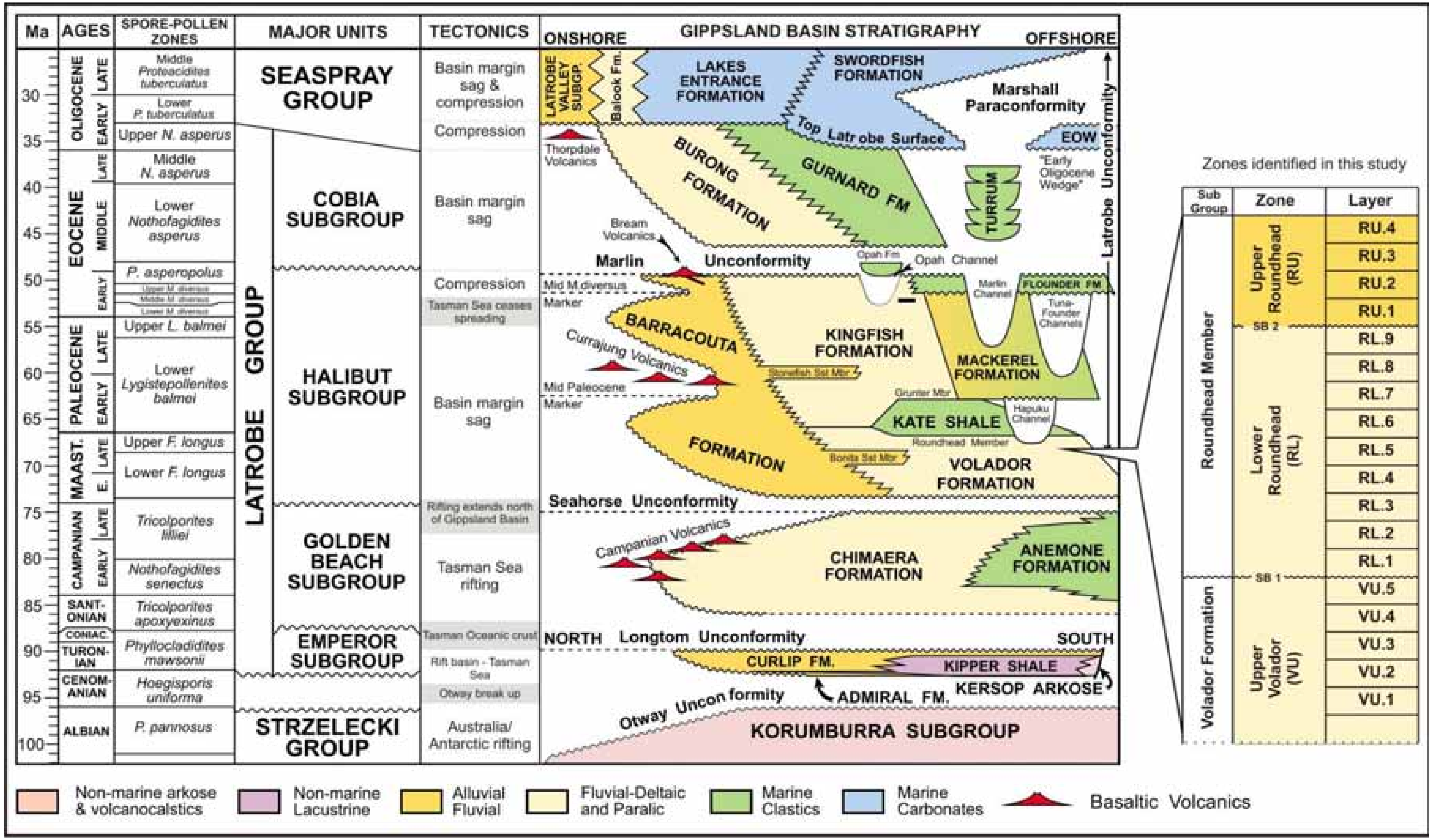


Figure 2.2. Stratigraphic units and unconformities within the Gippsland Basin. The interval of interest, the upper Volador Member and Roundhead Member were deposited below the Kate Shale in the Halibut Subgroup. Modified from Bernecker & Partridge (2001). Tectonics from Smith (1988), Bernecker and Partridge (2001) and Norvick and Smith (2001).

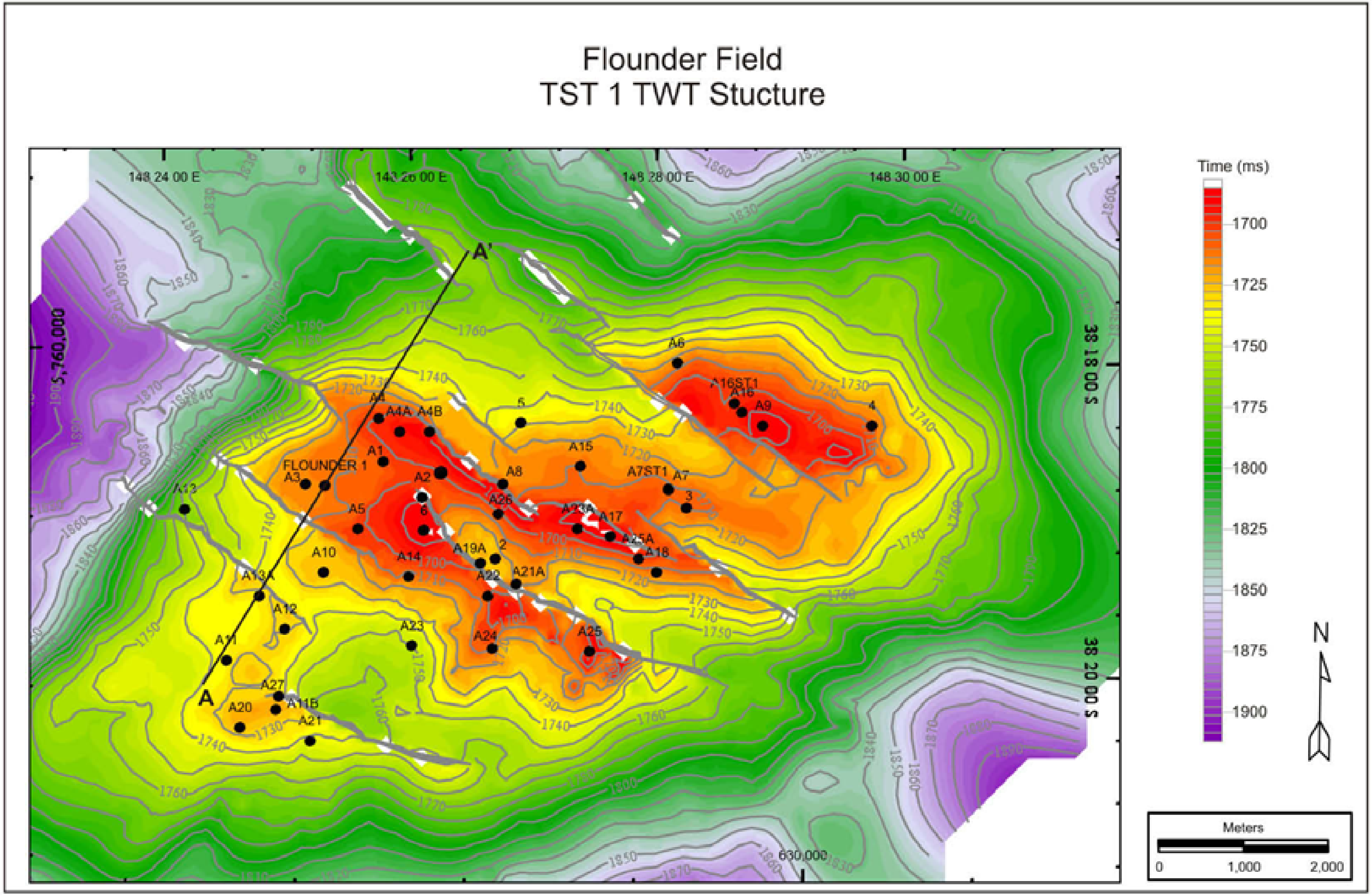


Figure 2.3. TST-1 TWT structure map of the Flounder Field. This surface is located approximately 150 m above the zone of interest. The line A-A' indicates the position of the seismic line shown in Figure 2.4.

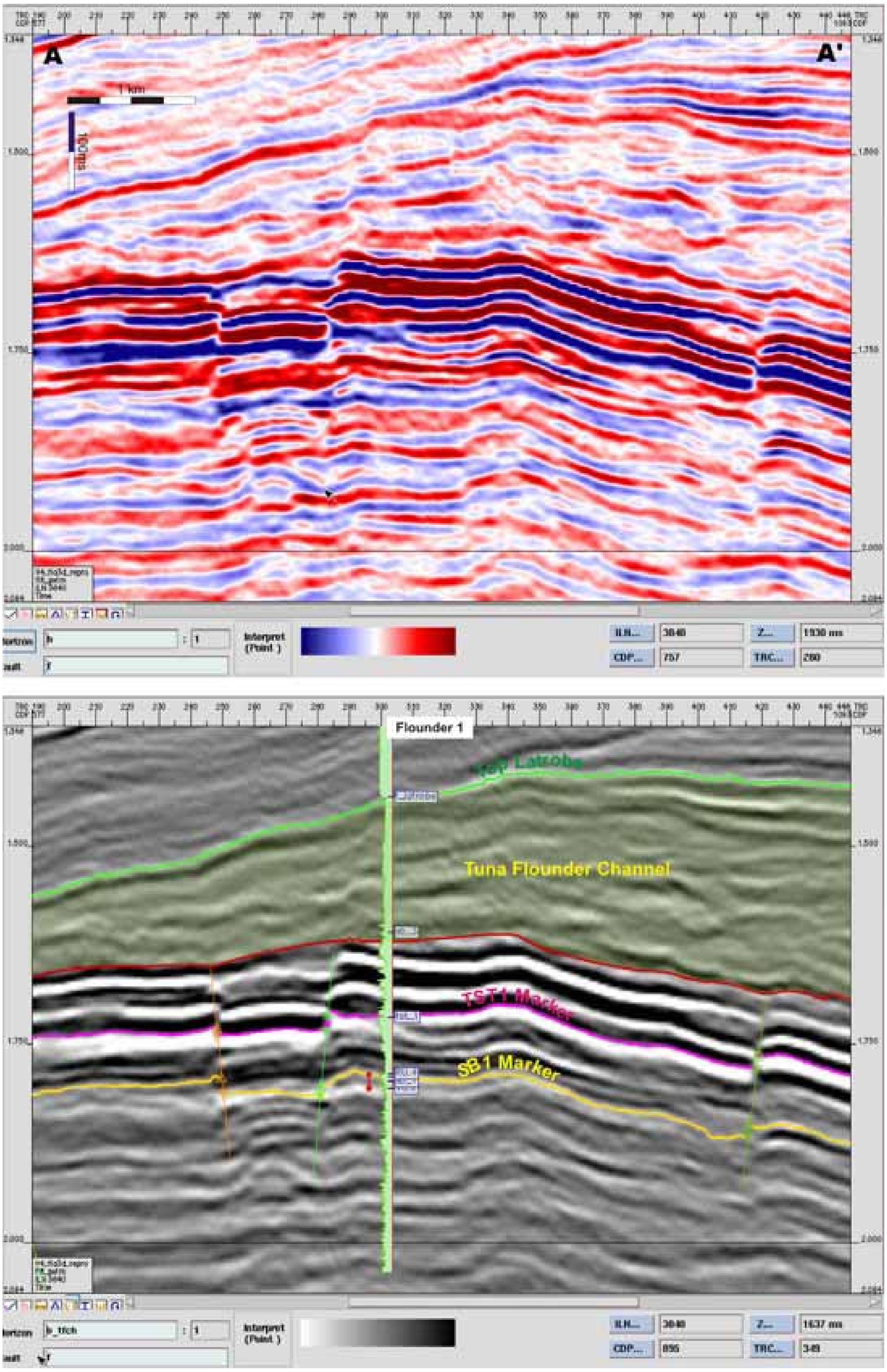


Figure 2.4. Seismic inline, showing the top of the Latrobe Group, the Tuna–Flounder channel and the faulted intra-Latrobe Group. The distance between the RU.4 marker and the VU.0 marker (red bar) is approximately 70 m. This image shows the interpreted surfaces in the Flounder Formation and the well picks. The reservoir interval (RU.4 to VU.0–red bar) is approximately one wavelength wide. A surface can be picked at this level (SB 1 marker: yellow) but is not a reliable pick across the field, as the quality of the seismic below the coals (strong reflectors) associated with the tst-1 marker is poor. The tst-1 marker (purple) is strong across the field, and is approximately parallel to the sb-1 marker. This is the surface that has been used as a base for the structural model of the field.

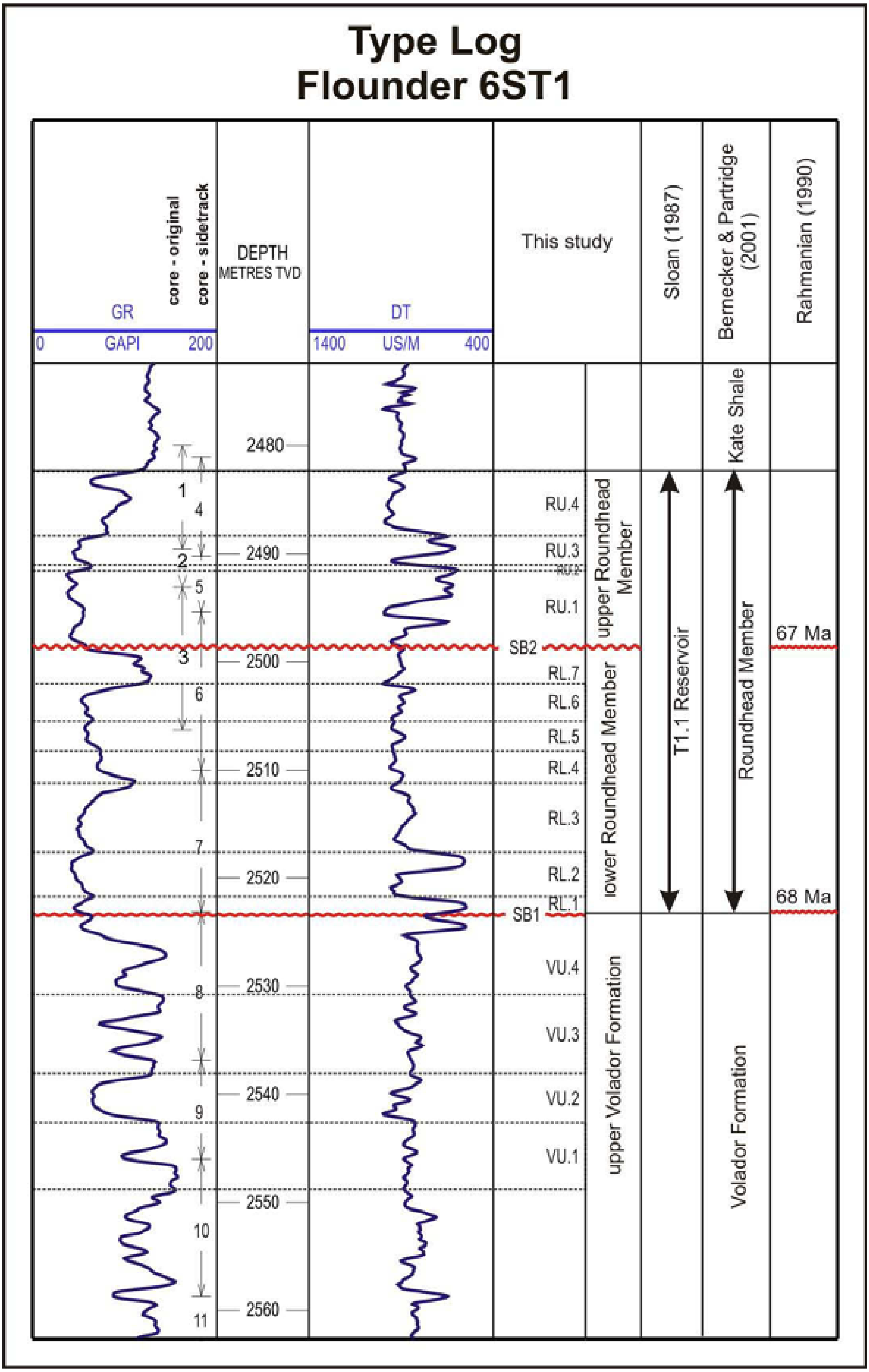


Figure 2.5. Type log for the Flounder Field—Flounder 6ST1 showing previous interpretations of the zone of interest. The low sonic values in the upper and lower Roundhead Member are caused by the presence of dolomite cement (Riordan, 1992).

Wireline Logs Available	Wells in Field																				
	f1	2	3	4	5	6	a1	a10	a11	a11b	a12	a13	a13a	a14	a15	a16	a16s	a17	a18	a19a	a2
depth	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
cali	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
cond	✓	✓	✓	✓	✓	✓															
drho	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓
dt	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓		✓
gr	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
hor_perm				✓		✓															✓
hor_por_pct	✓			✓		✓															✓
neut	✓																				
llm				✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓		✓	✓		✓
nphi					✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
pef							✓	✓	✓		✓	✓	✓	✓		✓		✓	✓	✓	✓
phie	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
phit	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
resd	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ress							✓	✓	✓		✓			✓	✓	✓		✓	✓	✓	✓
rhob	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
sp	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓			✓	✓			✓	✓		✓
swe	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
swt	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
vclay		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	
vsh	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Wireline Logs Available	Wells in Field																				
	a20	a21	a21a	a22	a23	a23a	a24	a25	a25a	a26	a27	a3	a4	a4a	a4b	a5	a6	a7	a7st	a8	a9
depth	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
cali			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
cond																					
drho			✓	✓	✓	✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
dt		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓		✓		✓			✓	✓
gr	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
hor_perm																					
hor_por_pct																					
neut																					
llm		✓		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
nphi	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
pef			✓	✓		✓	✓	✓	✓	✓	✓		✓	✓	✓	✓	✓	✓	✓	✓	✓
phie	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
phit			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
resd		✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
ress				✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
rhob			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
sp				✓	✓		✓	✓		✓		✓	✓			✓	✓				✓
swe			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
swt			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓
vclay			✓	✓		✓		✓	✓	✓		✓	✓	✓	✓	✓		✓	✓	✓	✓
vsh			✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓	✓

Figure 2.6. Wireline logs available in each well in the Flounder Field dataset.

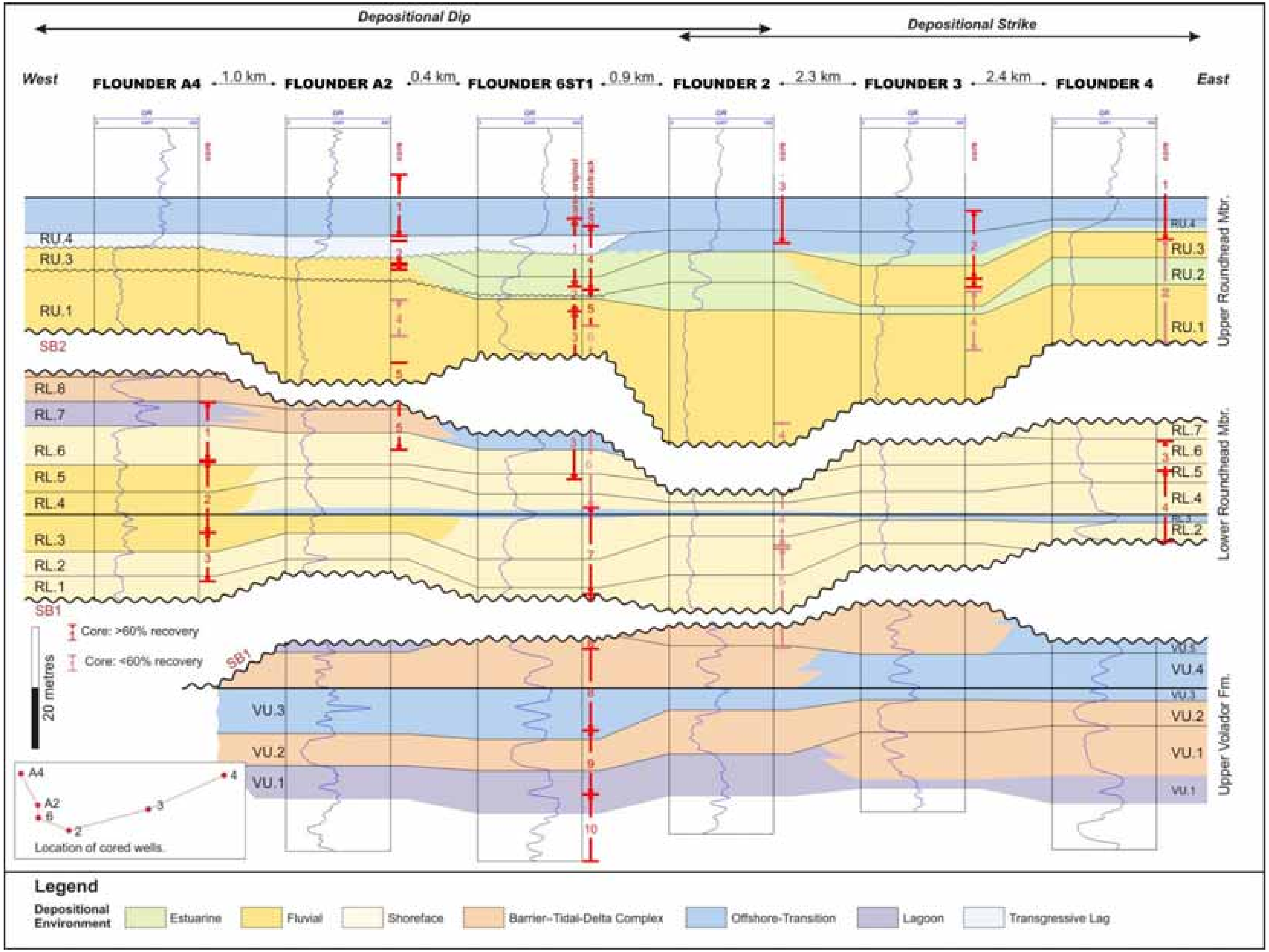


Figure 2.7. Flounder Field cores studied. Core recovery in the upper Roundhead Member is often poor. Two sets of core covering the upper Roundhead are available in the Flounder 6 well, as the original well was sidetracked, and core was also cut in the sidetrack. Each section is hung on a field-wide flooding surface (heavy black line). The datum for the upper Roundhead Member is a flooding surface above the RU.4 unit. The datum for the lower Roundhead Member is a flooding surface at the top of the RL.3 unit. This surface is the most widespread flooding surface within the lower Roundhead Member. The upper Volador Formation is hung on the VU.3/VU.4 boundary. The VU.3 unit represents a brief marine transgression the covered the entire field with offshore transition sediments.

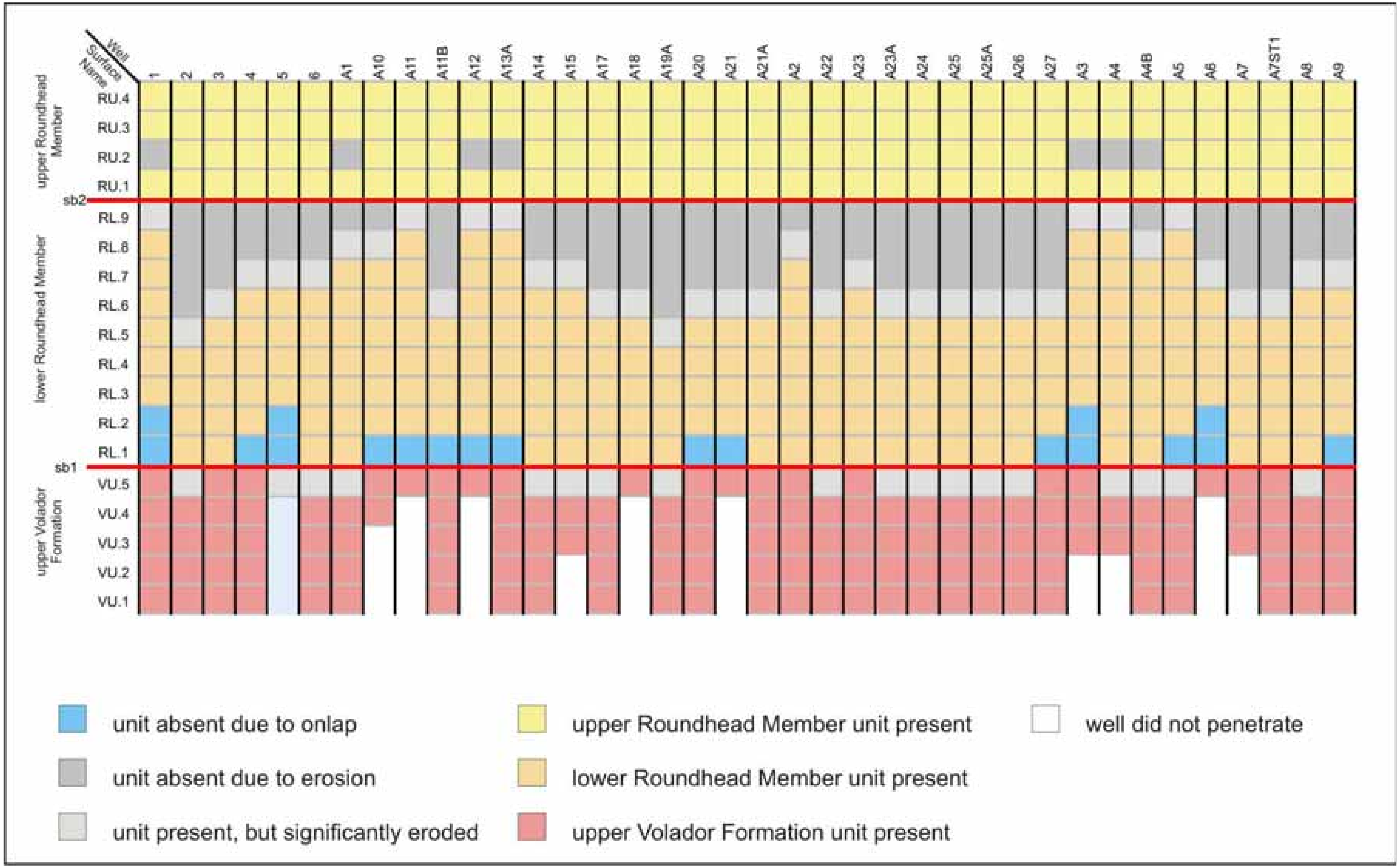


Figure 2.8. Surfaces interpreted in the upper Roundhead Member to upper Volador Formation interval.

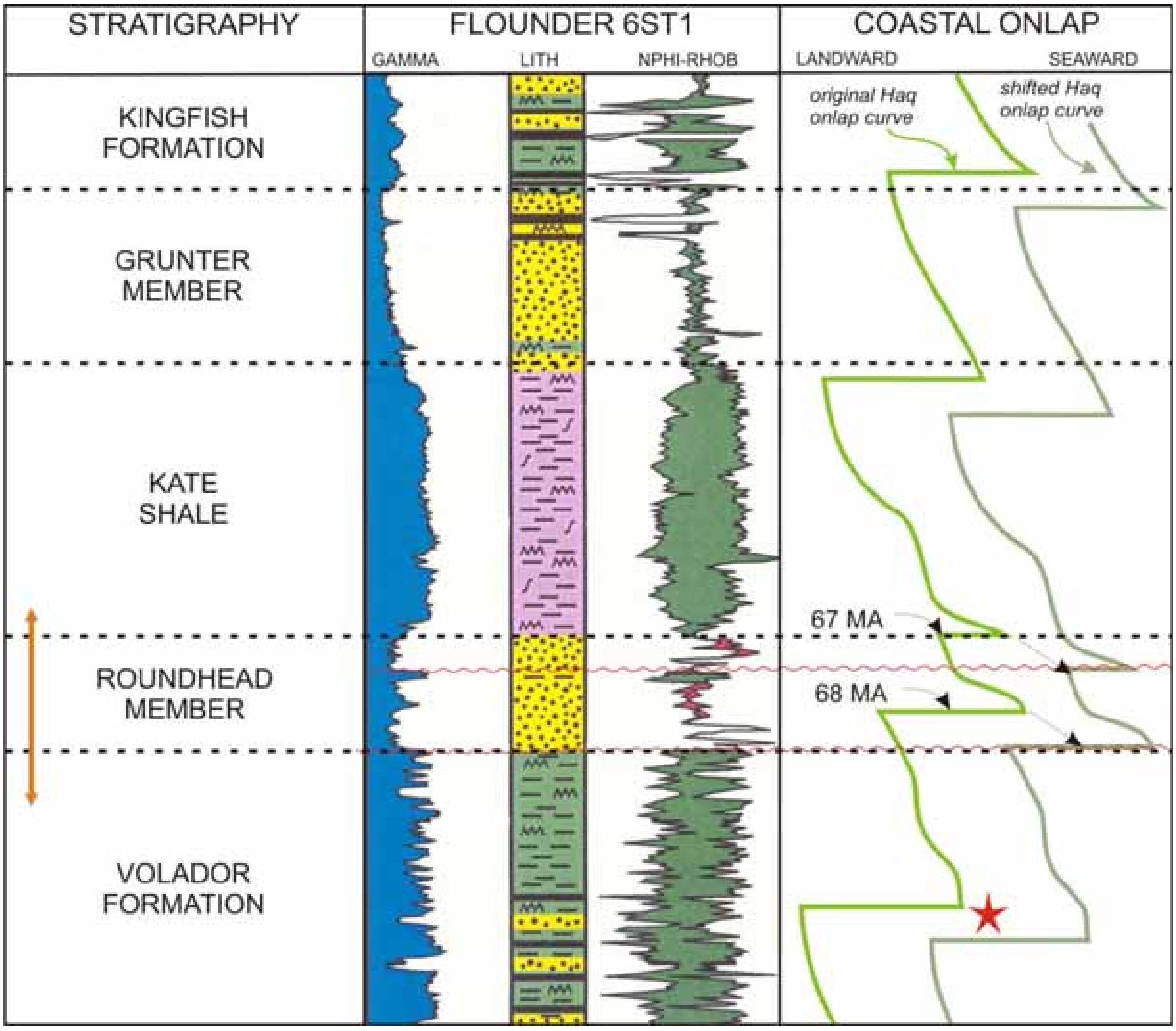


Figure 2.9. Flounder 6 stratigraphy and global sea-level curves. This diagram shows that the two sequence boundaries interpreted in the Flounder Field (SB1 and SB2) *may* be associated with global events identified by Haq et at (1988) (grey curve) if the curve is shifted down slightly (green curve). However, as can be seen from the large relative sea level fall in the Volador Formation (red star) that has no apparent influence on a paralic section, the association may be coincidental. The orange arrow indicates the approximate cored interval studied in this project. Modified from (Partridge, 2003) and (Haq et al., 1988).

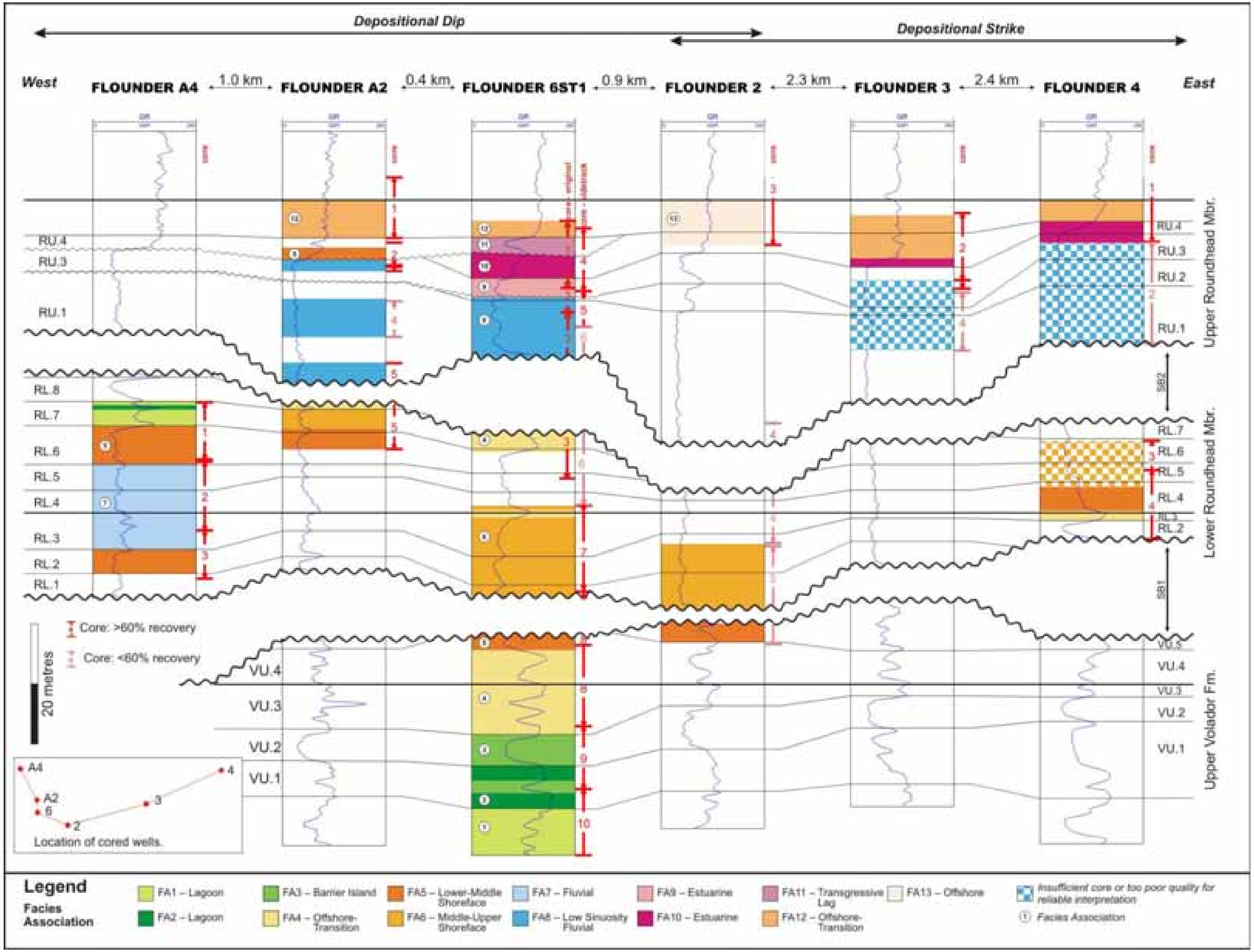


Figure 2.10. Facies Associations and stratigraphic interpretation from core. Each sequence is hung on a regional flooding surface (heavy black line). The upper Volador Formation is hung on the top of the VU.3 unit, the lower Roundhead Member is hung on the top of the RL.3 unit and the upper Roundhead Member is hung on a flooding surface above the top of the RU.4 unit. Core intervals marked in pale red had poor recovery and did not usually provide useful information.

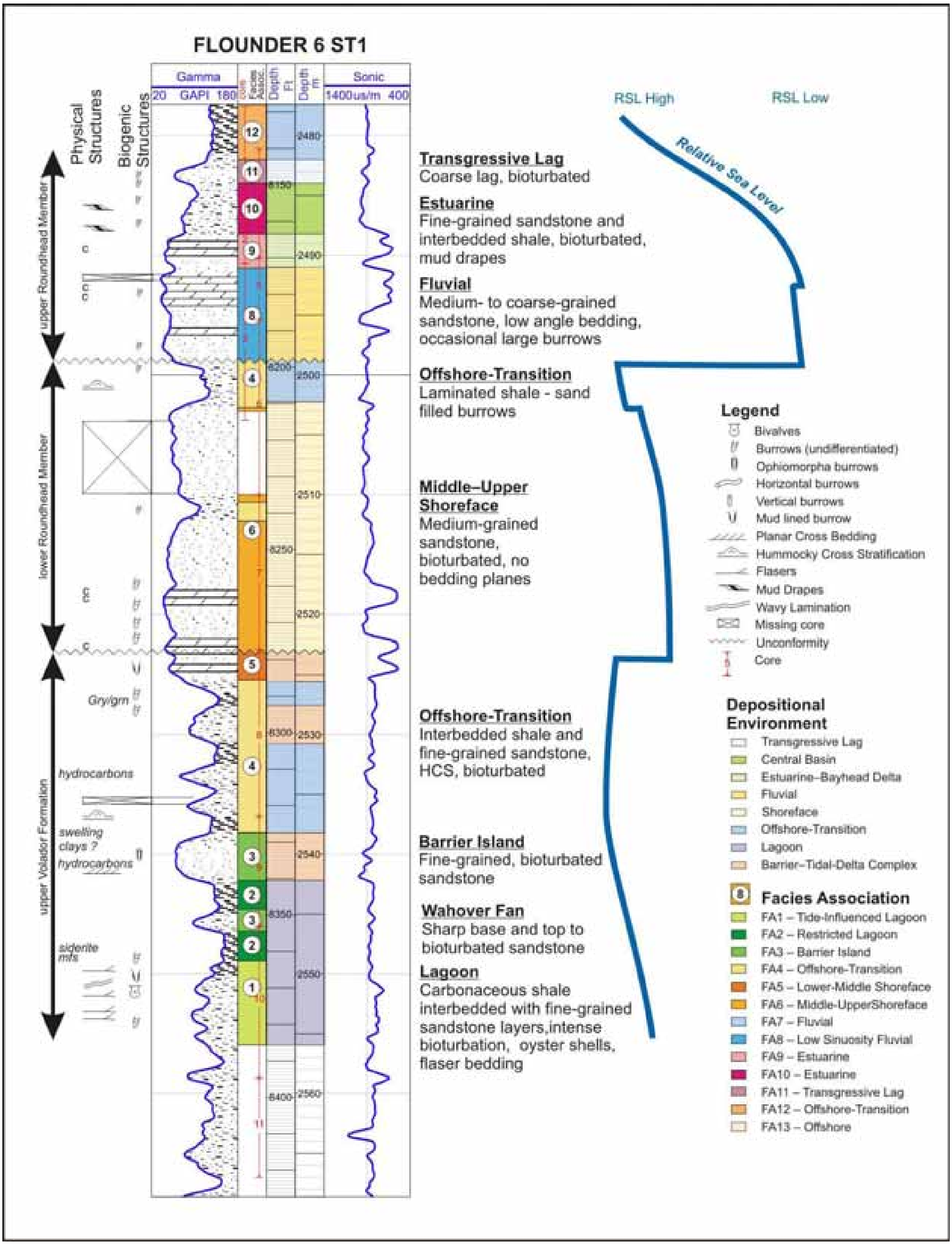


Figure 2.11. Core log, Flounder 6 ST1 showing key sedimentary structures and the Facies Associations. The depositional environment categories are those that are used in the geological models. Depth scales are presented in feet as well as metres as the core, which was cut in 1977, is marked in feet, so was logged in feet.

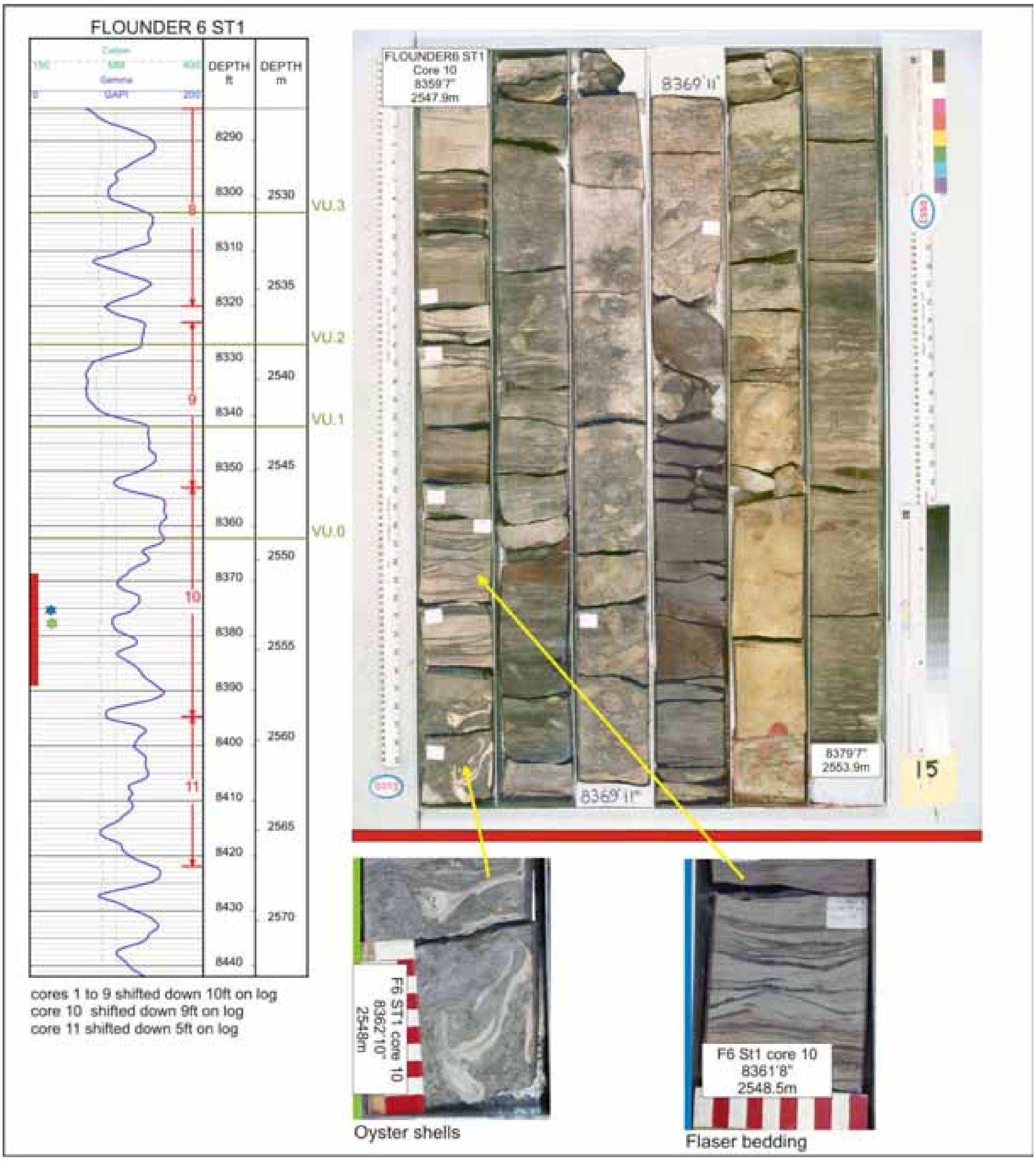


Figure 2.12. Flounder 6 ST1 core 10, upper Volador Formation, Facies Association 1, showing flaser bedding and oyster shells. The stars on the wireline log show the position of the detailed core photos. The sandy layer in the second row from the left (top photo) may be part of a washover or tidal delta complex.

In this, and subsequent figures, the stars on the wireline log show the position of the detailed core photos. The colour of the stars corresponds to the colour of the stripe on the edge of the picture. The red stripe on the wireline log indicates the interval covered by the main core photos.

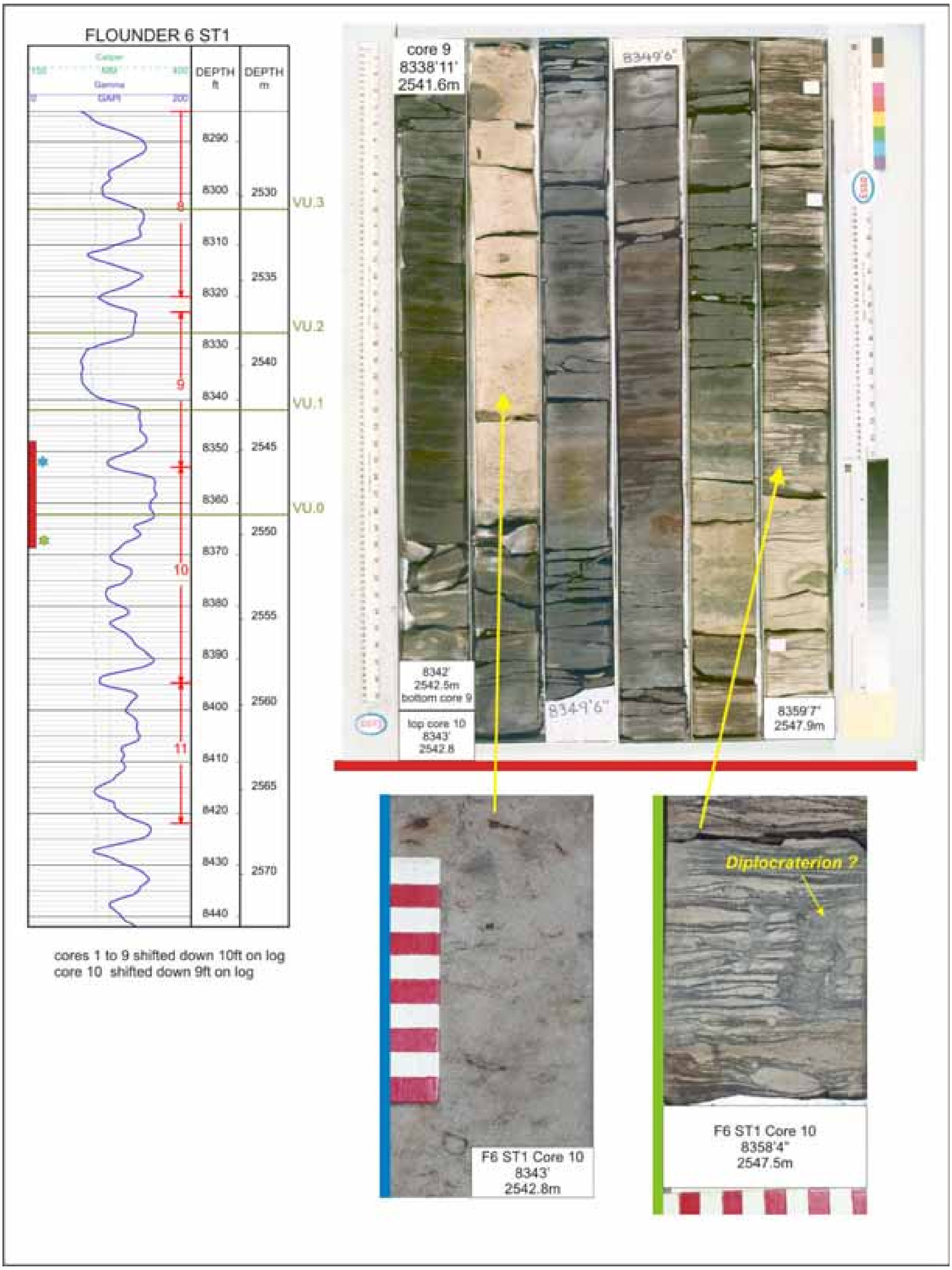


Figure 2.13. Flounder 6ST1 core, VU.0 and VU.1 units. Upper Volador Formation, showing detail of a washover fan and diplocraterion ichnofacies. The carbonaceous shales in the far right and centre of the core tray are Facies Association 2. The washover fan (Facies Association 3) (bottom left) has a sharp base and top, indicating rapid deposition into a normally quiet environment. The red/brown blobs that occur at various intervals in the core are post depositional siderite nodules.

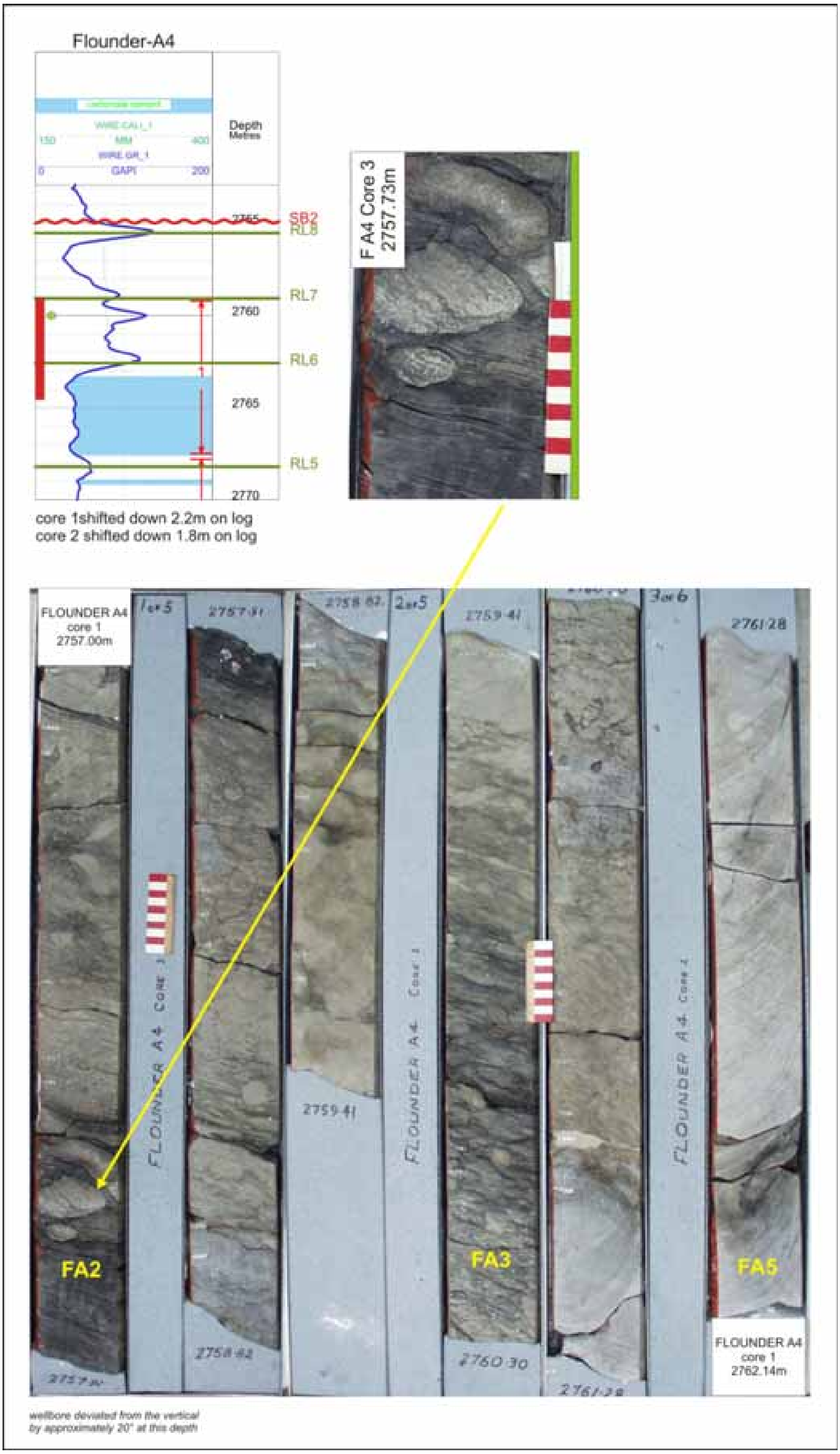


Figure 2.14. Flounder A4, upper Roundhead Member RL.5 and RL.6 units. Note the sand-filled burrows that penetrate the black carbonaceous shale layer (FA2). Thin layers of sandstone, and occasional grains can also be seen within the layer. These indicate that the shale was deposited in quiet water that was not far from a sandy source—such as in a back barrier lagoon environment. The outline of the burrow (top right) shows that the burrow deformed the surrounding sediment.

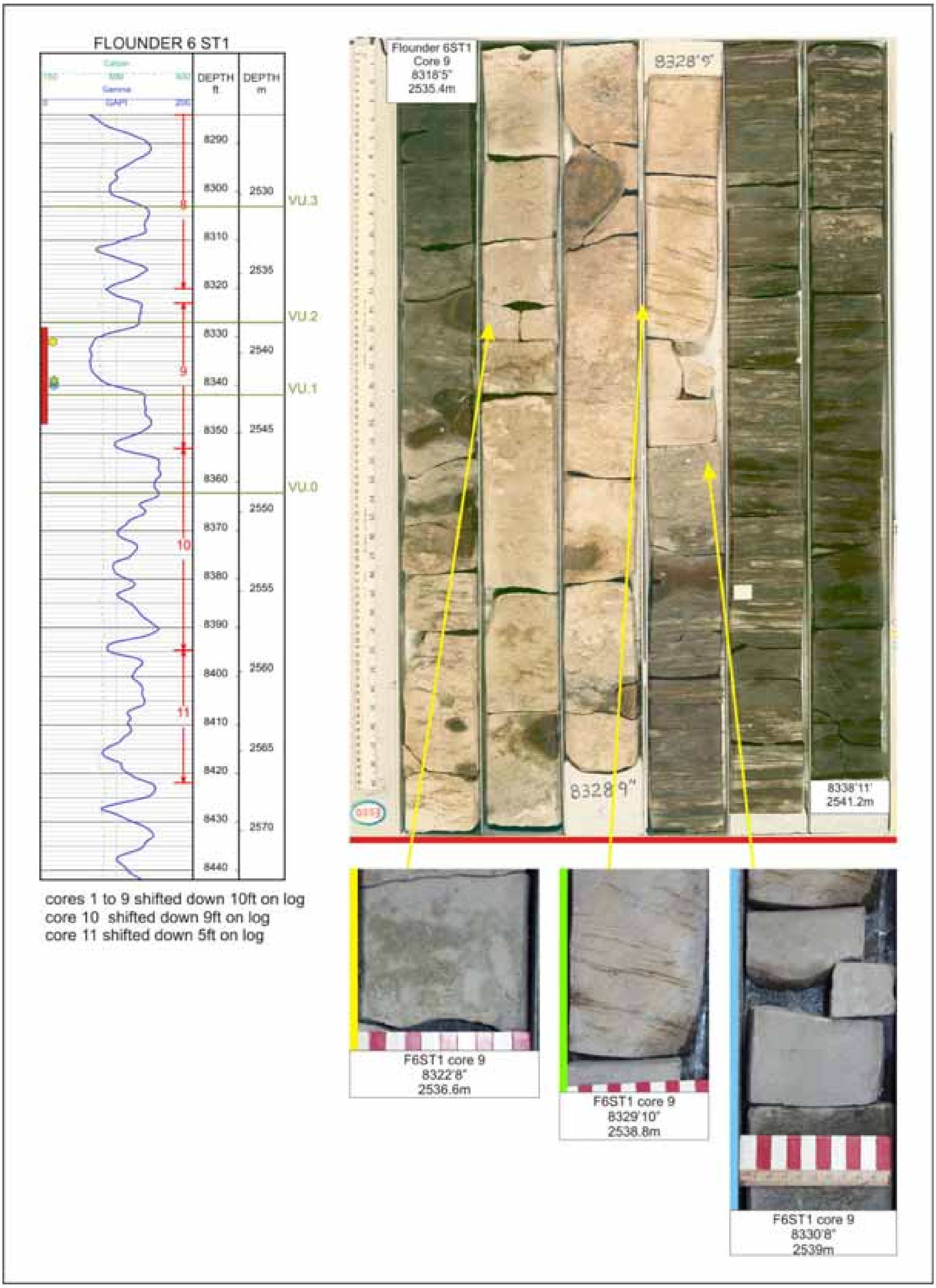


Figure 2.15. Flounder 6 ST1, core 9. VU.2 unit. Fine-grained, bioturbated sandstone bed (FA3) overlying carbonaceous silt with interbedded thin layers of sandstone (bottom right). The transition to clean sandstone is abrupt, and contains climbing ripples (bottom middle). Higher in the bed, biogenic activity resumes and the sandstone becomes bioturbated (bottom left). The dark red patches are siderite nodules. This bed is interpreted as a barrier shoreface/tidal delta complex deposit.

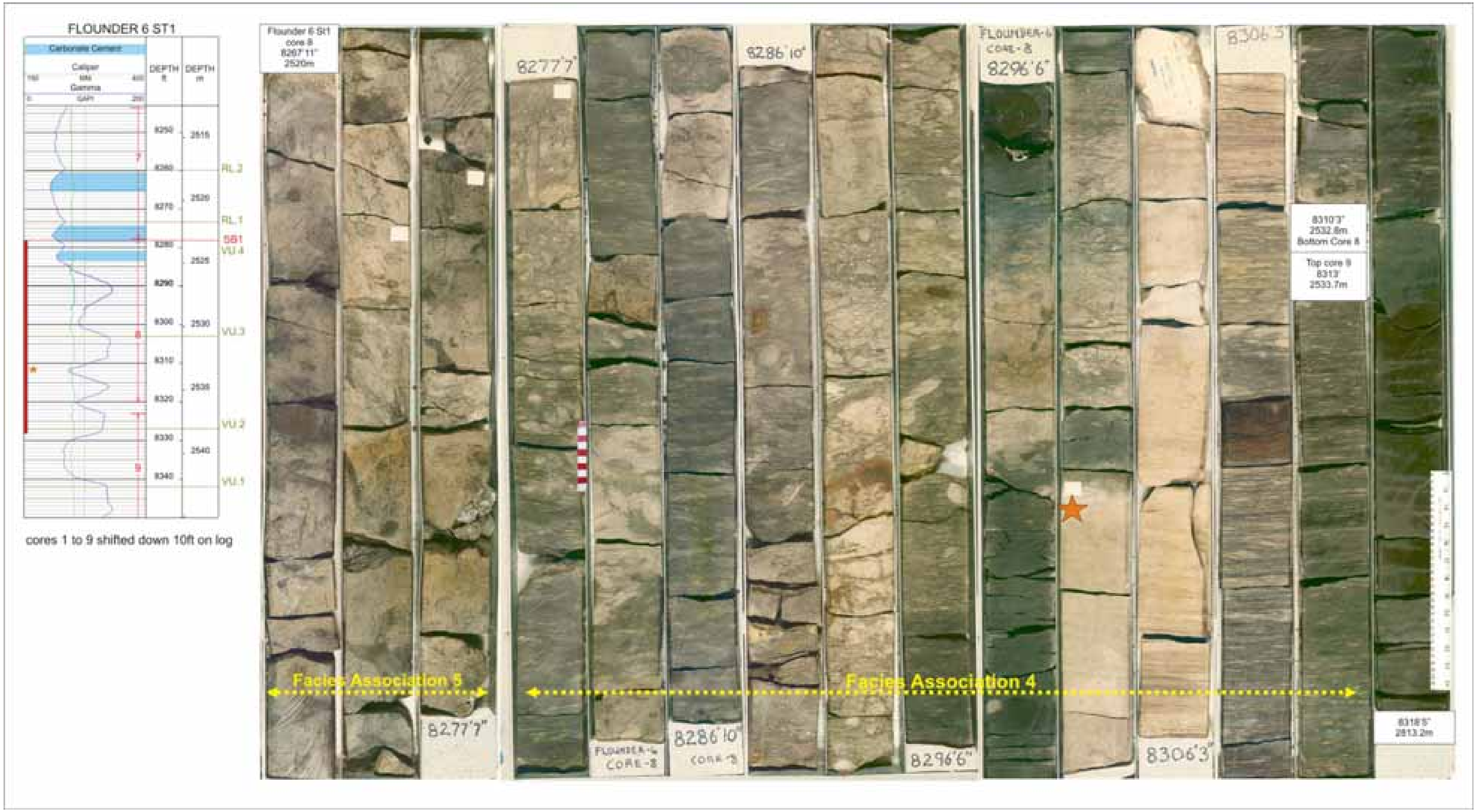


Figure 2.16. Flounder 6 ST1, VU.3 & VU.4. This interval shows a series of sandstone beds (one indicated by the orange stars on core and log), interbedded with offshore marine shales (FA4). FA5 is the highly bioturbated sandstone on the left

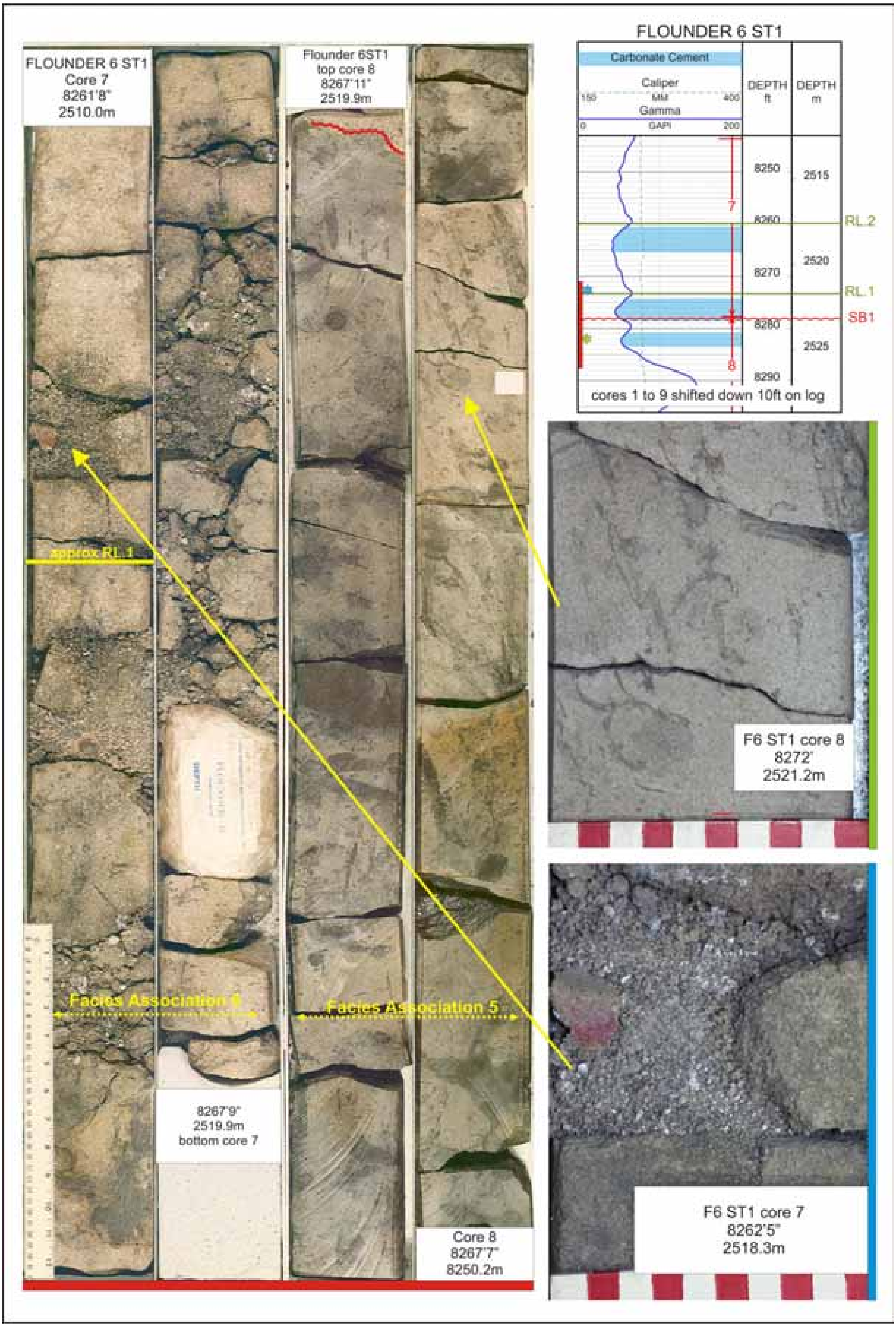


Figure 2.17. Flounder 6 ST1 core, VU.4 and RI.1 units. Fine-grained, well cemented, bioturbated lower-shoreface sandstone of the upper Volador Formation (bottom right) and medium grained, poorly cemented, middle shoreface sandstone of the lower Roundhead Member (top right). SB1 can be seen just below the top of core 8 (red line).

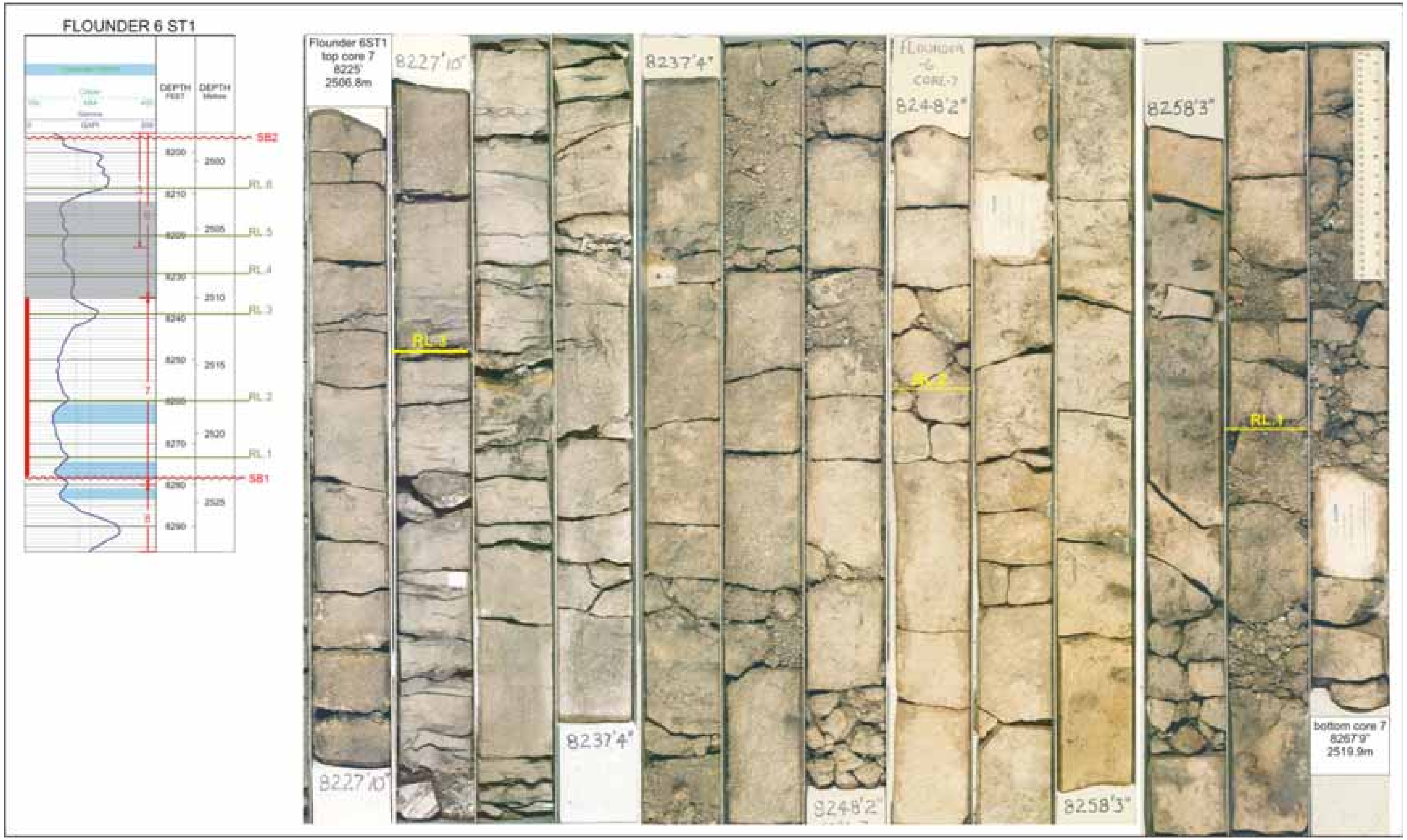


Figure 2.18. Flounder 6ST1, core 7, RL.1 to RL.3 unit, FA 6. Unit boundaries are approximate only. Features that appear to be shale breaks on the wireline logs, such as the top RL.3, are not always associated with distinctive lithology changes in the core. The top RL.2 boundary is particularly difficult to identify on core photos in this well. It was not identified during core logging as the detailed stratigraphic interpretation was completed after the core was logged. Note the change in bioturbation in the RL.2 unit from common mud-lined burrows at the base to infrequent activity in the cleaner, coarser sandstone at the top of the unit

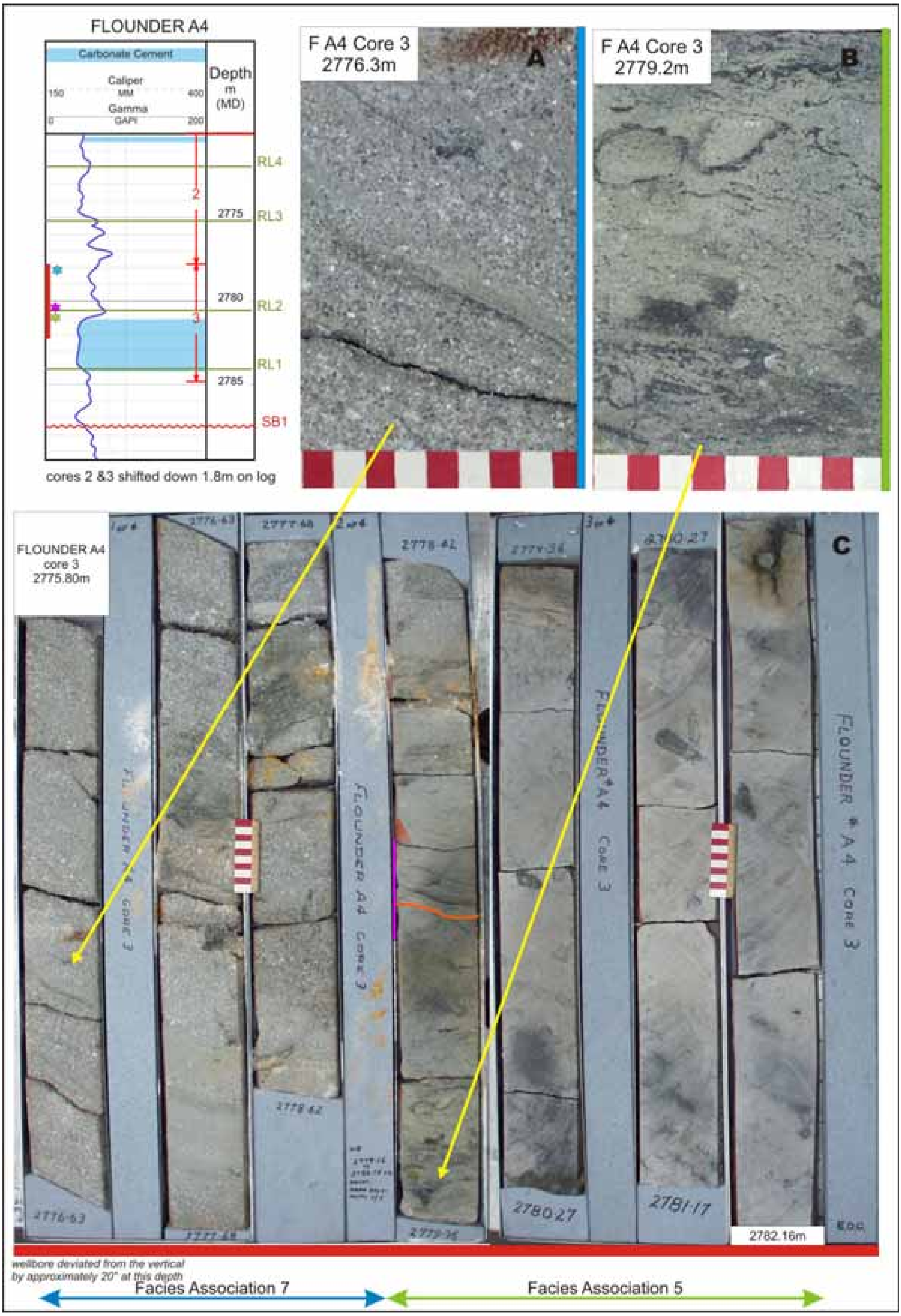


Figure 2.19. Flounder A4. Facies Associations 5 and 7. FA5 (right) is interpreted as middle shoreface and FA7 as a fluvial channel. The pink star and bar indicate the location of the core shown in Figure 2.20. The boundary between the RL.2 and RL.3 (orange line) unit is picked on a gamma spike. The core indicates that this spike is not due to the presence of a flooding surface shale. It is most likely to be caused by an increase in carbonaceous material, such as is shown in image B.

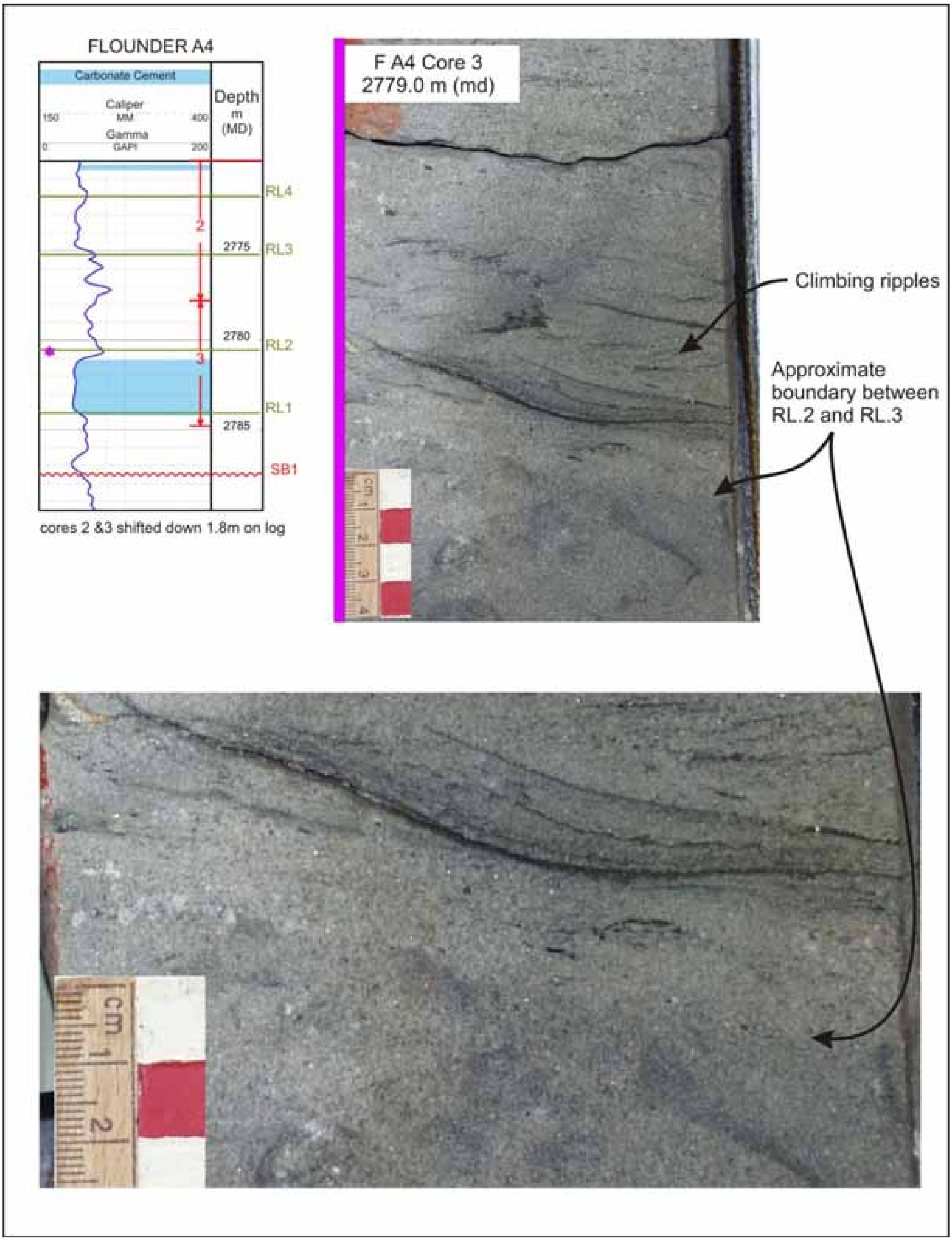


Figure 2.20. Flounder A4. Facies Association 7. Climbing ripples. These climbing ripples occur just above where the lithology changes from bioturbated sandstone (lithology one) to coarse low-angle bedded sandstone. There appears to be a subtle erosion surface with possible lag (white specks) at the boundary between the RL.2 and Rl.3 units. The RL.2 unit is interpreted as a middle- to upper-shoreface environment. The RL.3 unit is interpreted to have been deposited in a fluvial channel. The climbing ripples indicate rapid deposition, while the lack of bioturbation suggests a change to an environment less suited to marine organisms.

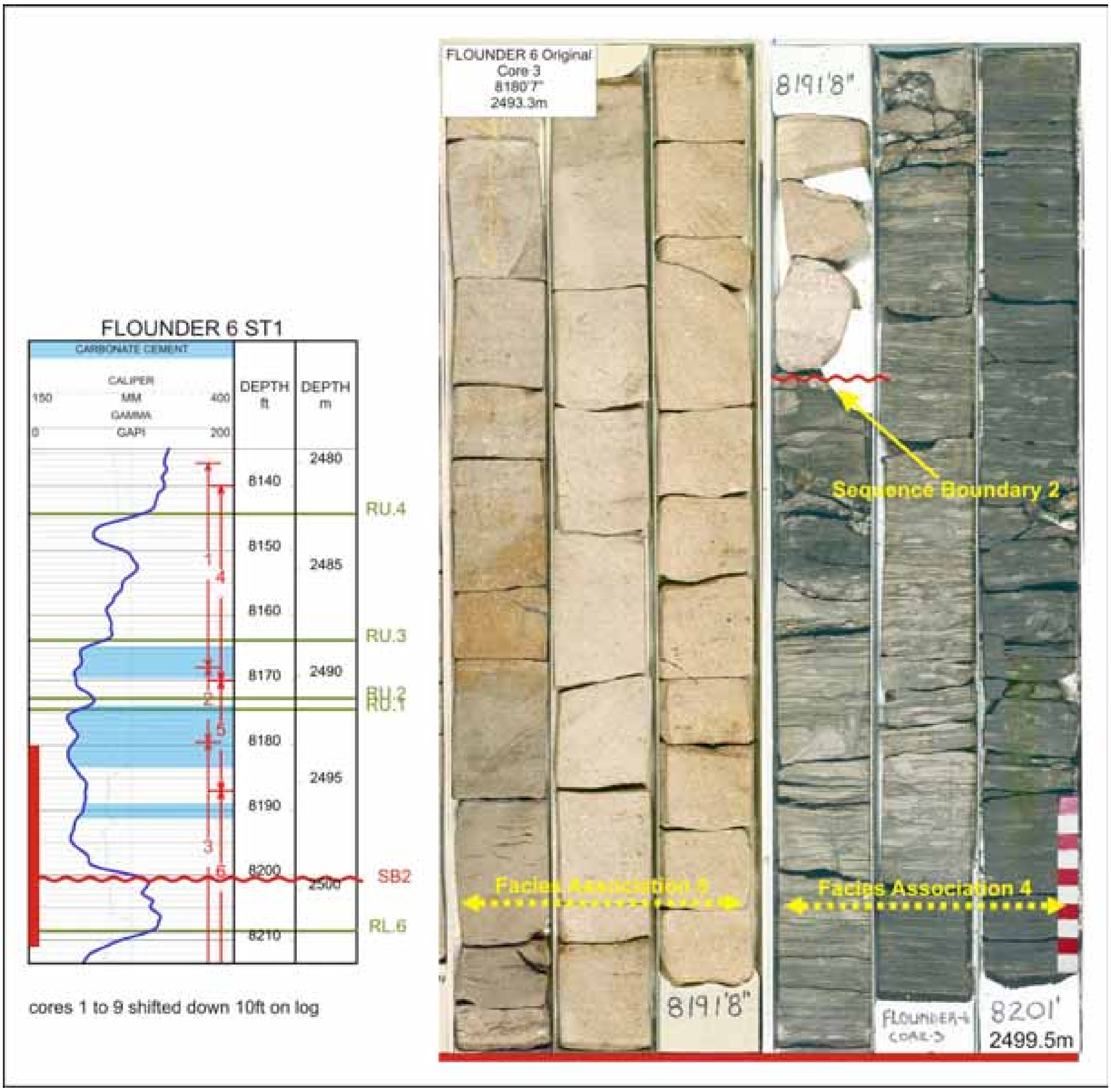


Figure 2.21. Flounder 6 core 3, RL.7 and RU.1 unit, showing SB2. FA4 (offshore-transition) is overlain by FA8 (low sinuosity fluvial). The abrupt change in lithology indicates a significant downward shift in relative sea level. The field wide stratigraphic interpretation of this boundary indicates that up to 20 m of section has been lost at this boundary.

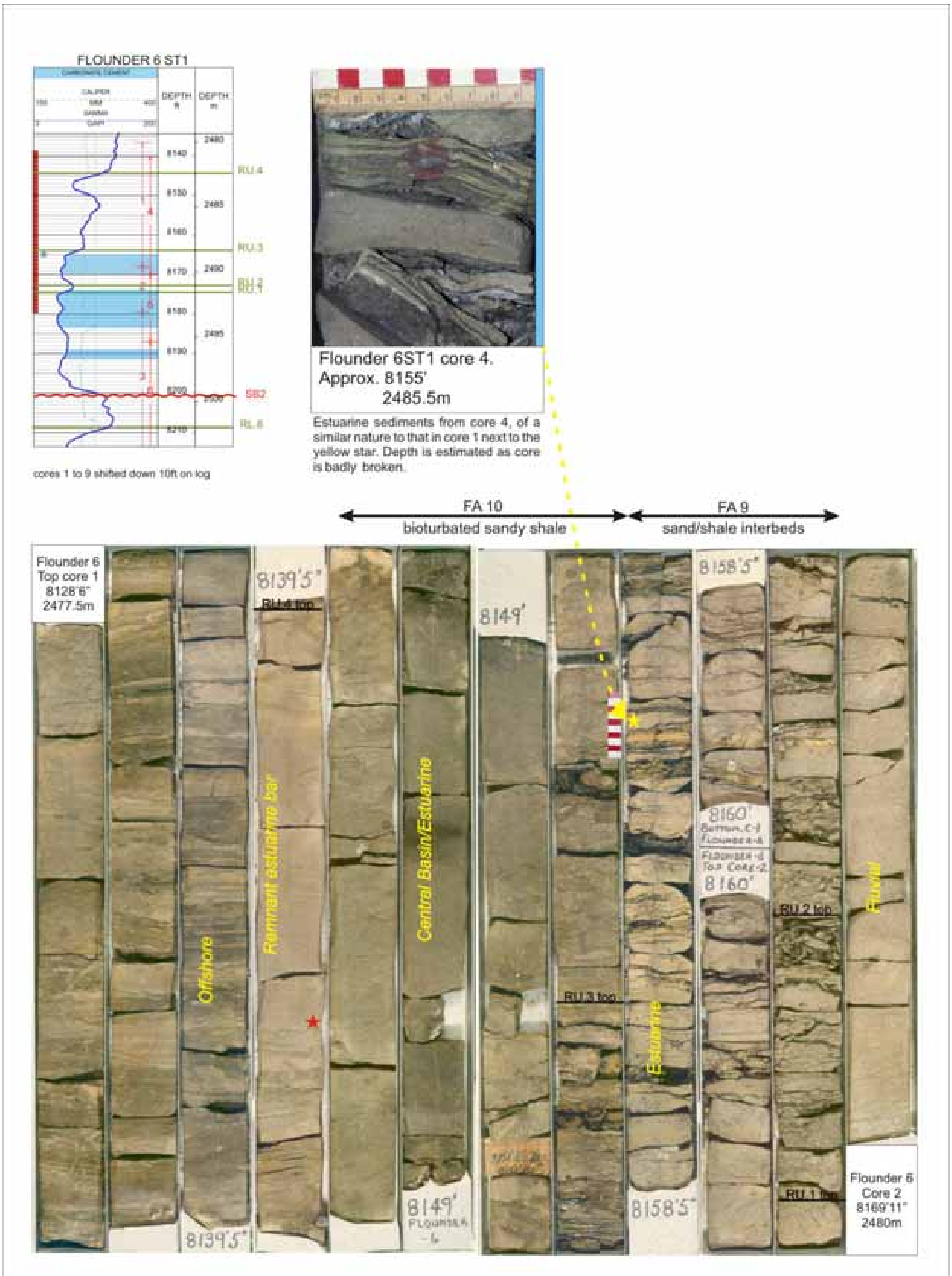


Figure 2.22. Upper Roundhead Member cores 1 and 2, Flounder 6. These cores cover the RU.1, RU.2, RU.3 and top of RU.4 units. A progression from fluvial, to estuarine and central basin to offshore is present. The RU.2 unit has a significantly higher gamma response than the overlying RU.3 unit despite the visual similarity between the units. The red triangle indicates the position of the transgressive lag seen in core 4 (sidetrack well) (see Figure 2.25).

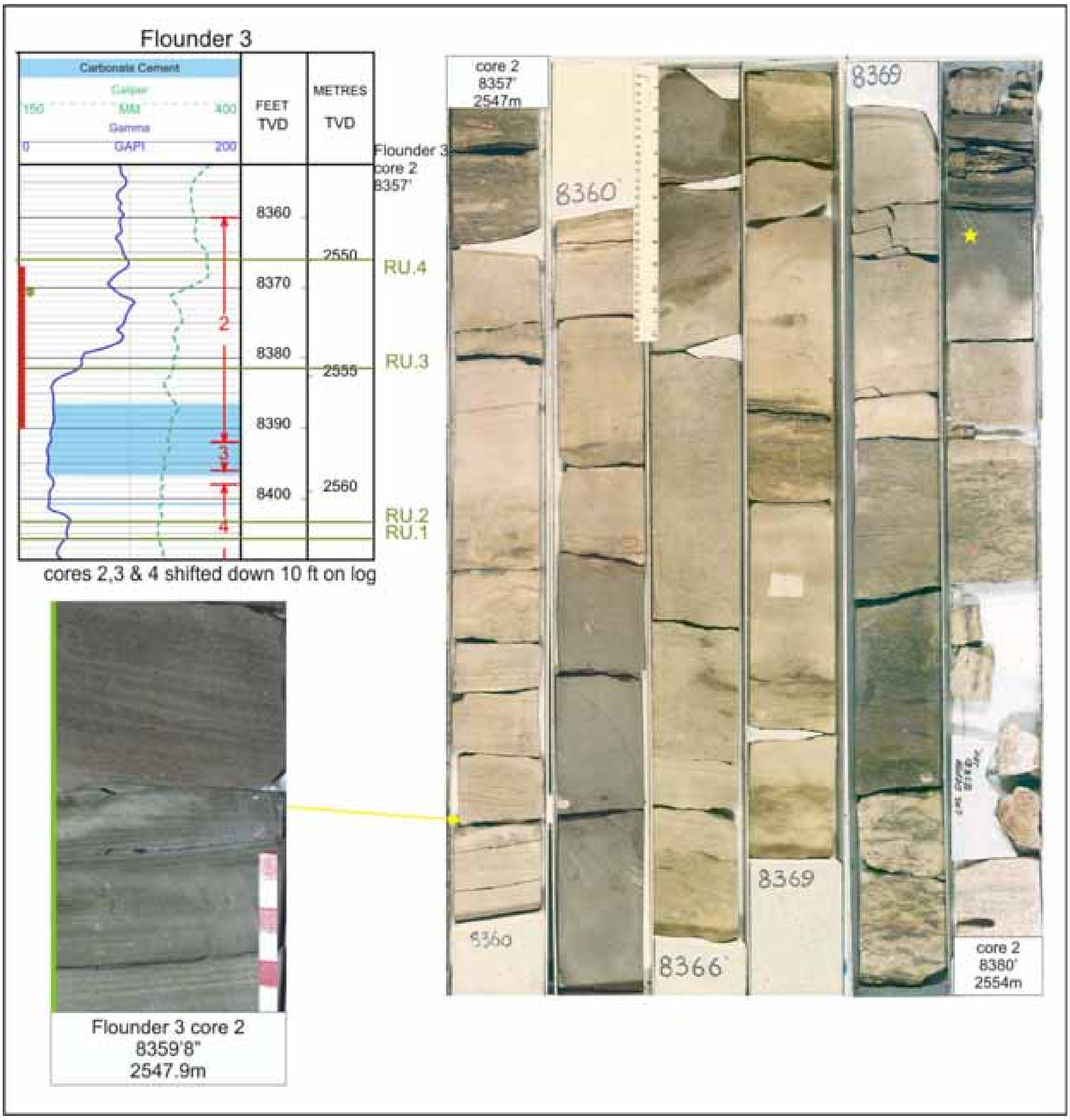


Figure 2.23. Flounder 3, core 2, RU.4 unit. Interbedded sandstone and shale packages. Planar bedding is visible in many of the sandstone beds, suggesting rapid deposition in an environment not hospitable to many burrowing organisms. The shale and muddy sandstones are generally intensely bioturbated. An estuarine depositional environment is interpreted for this interval. Note: the dark area near the yellow star appears to be wet.

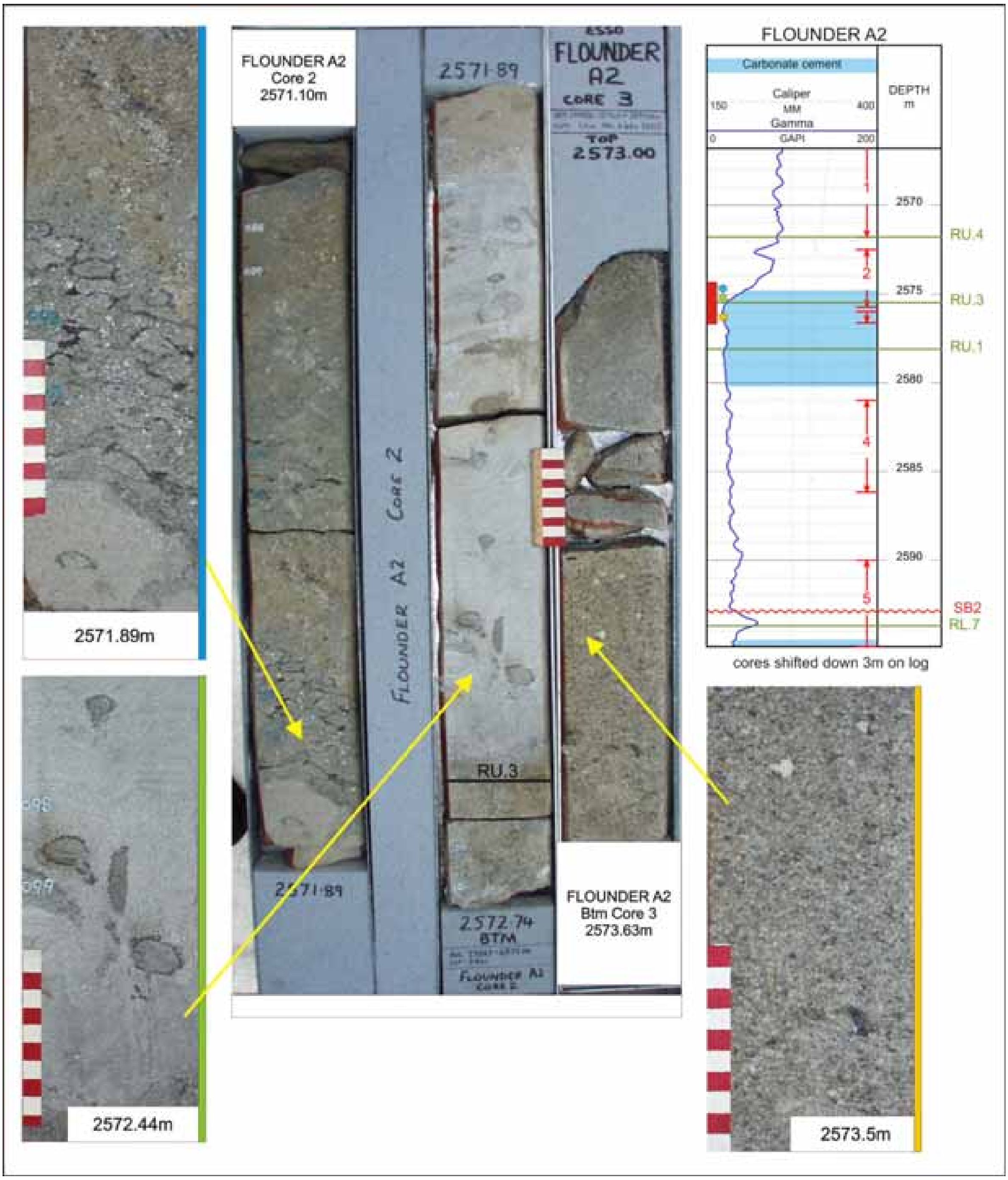


Figure 2.24. Flounder A2 cores 2 & 3, RU.3 and RU.4 units. Transition from coarse-grained fluvial sediments (right) to middle shoreface (bottom left) to lower shoreface sediments (top left). Transition from fluvial to marine conditions appears to have been relatively rapid. The estuarine and central basin facies seen in Flounder 6 at this depth are absent in this location.

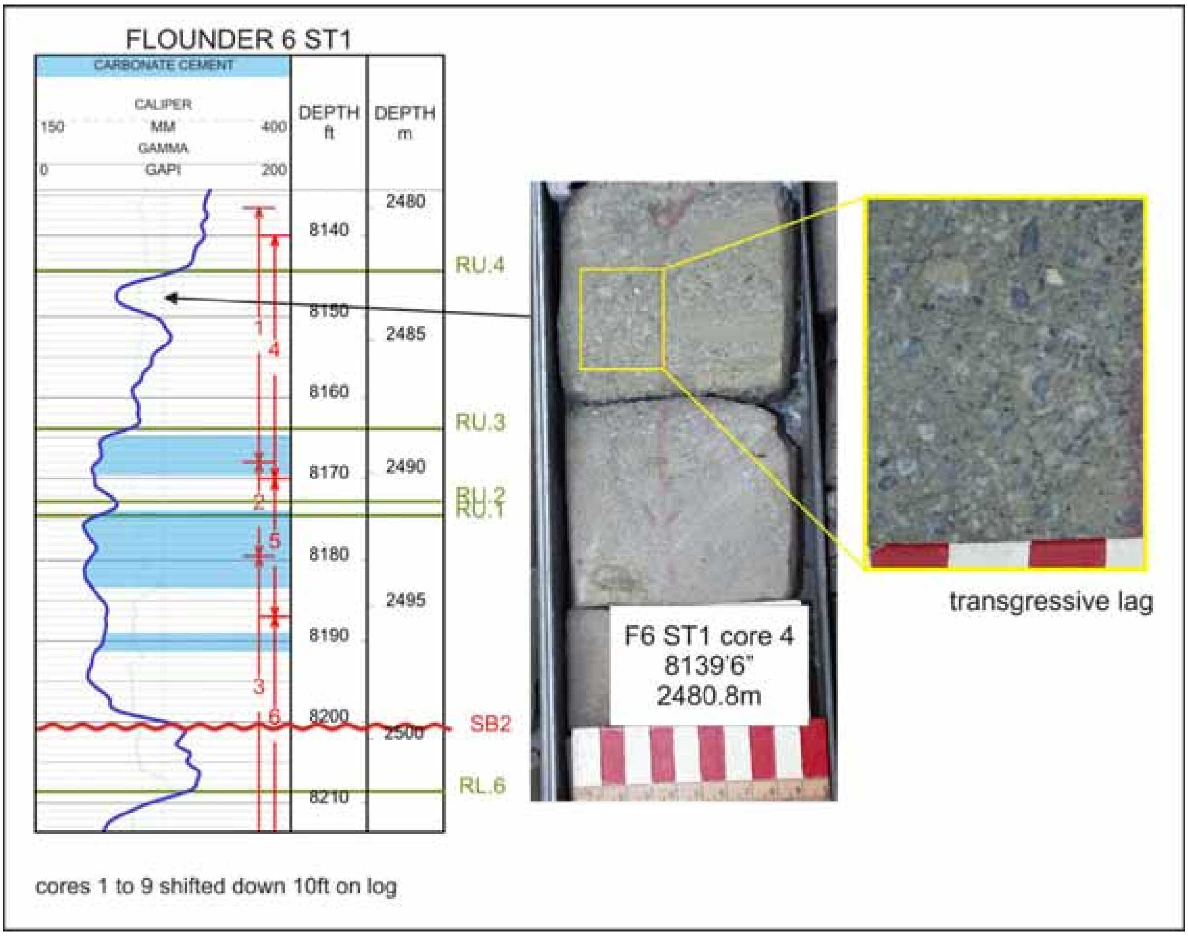


Figure 2.25. Flounder 6ST1 core 4, RU.4 unit, showing a transgressive lag (FA11) at the top of the upper Roundhead Member.

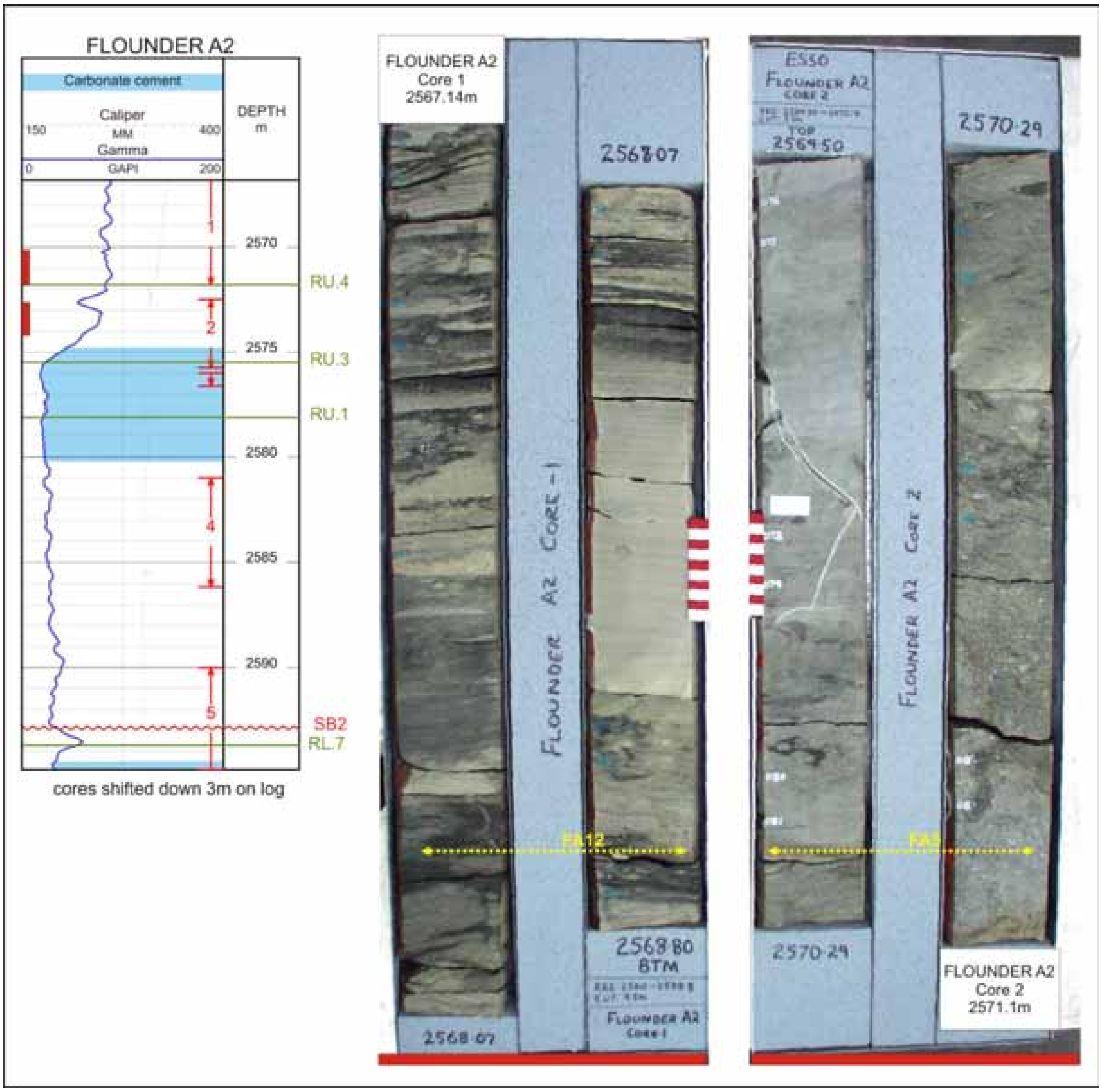


Figure 2.26. Flounder A2, cores 1 & 2, RU.4 unit. Transition from lower shoreface conditions (right) to open marine, offshore (left) with storm deposits.

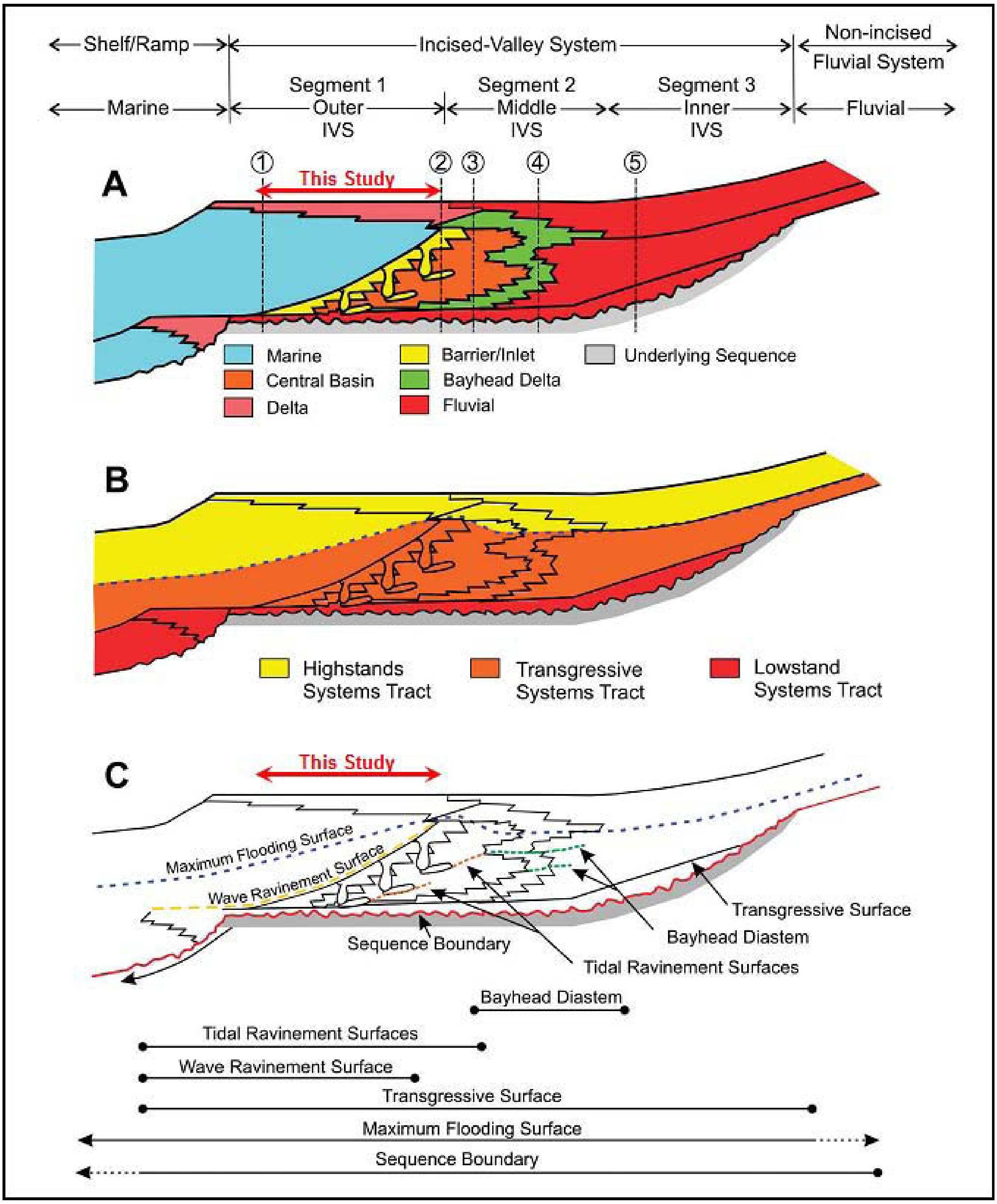


Figure 2.27. Idealised section of an incised valley system. Diagram A highlights the complex arrangement of depositional environments present in a wave-dominated estuary. Diagram B shows the systems tracts, and Diagram C shows key stratigraphic surfaces. This model contains the elements seen in the upper Roundhead Member—lowstand fluvial, bayhead delta, central basin and wave ravinement surface. Elements seen in the Flounder Field indicate that it was probably located at the seaward end of the incised valley, somewhere between location 1 and 2 on diagram A. Modified from Clifton (2006), modified from Zaitlin et al. (1994).

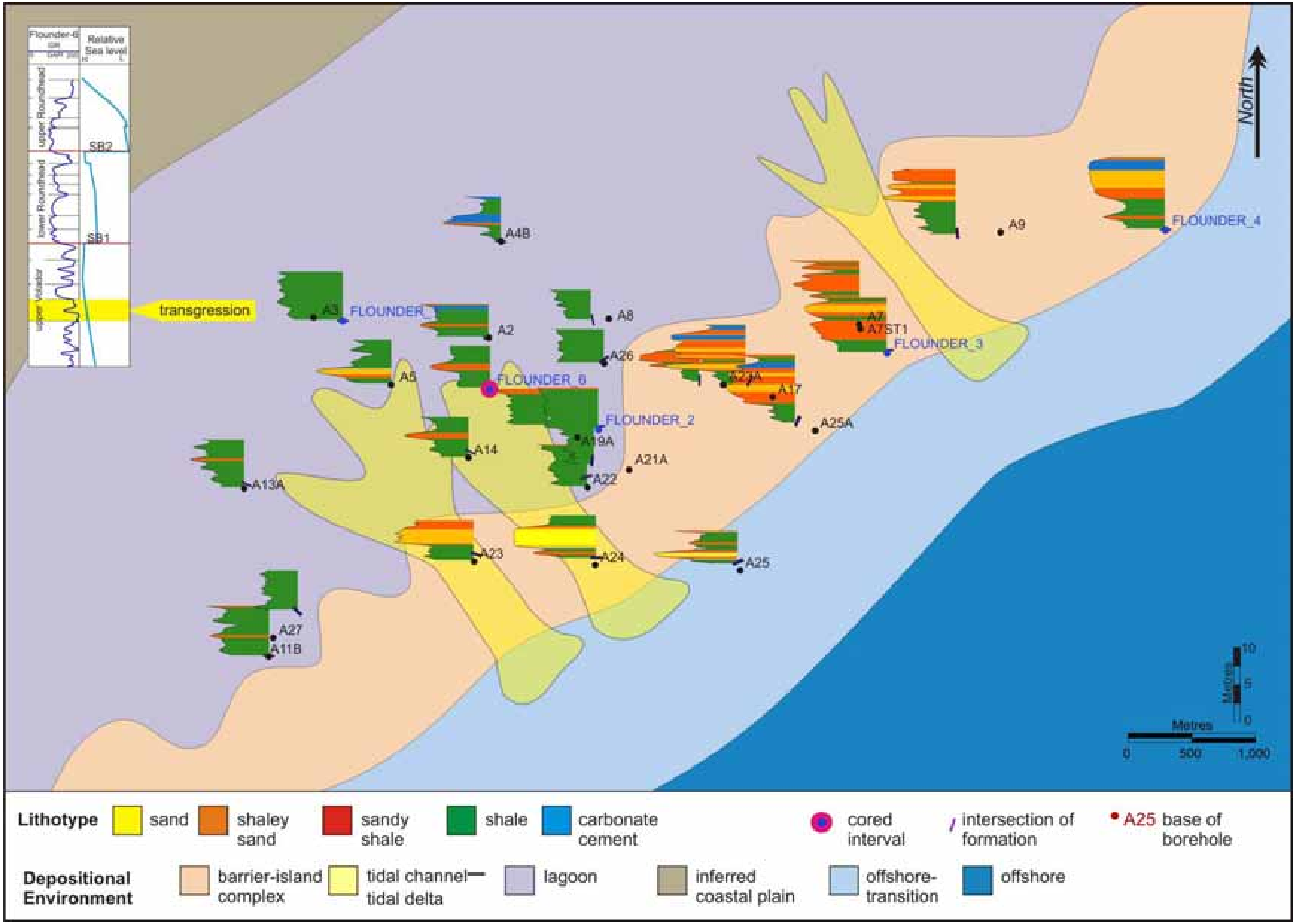


Figure 2.28. Log signature plot and palaeofacies map of the VU.1 unit. During this interval Flounder 6 is landward of sand-rich sections in other wells, thus supporting the core interpretation of a barrier lagoon system. For larger version of all log signature plots please see *Appendix 2*.

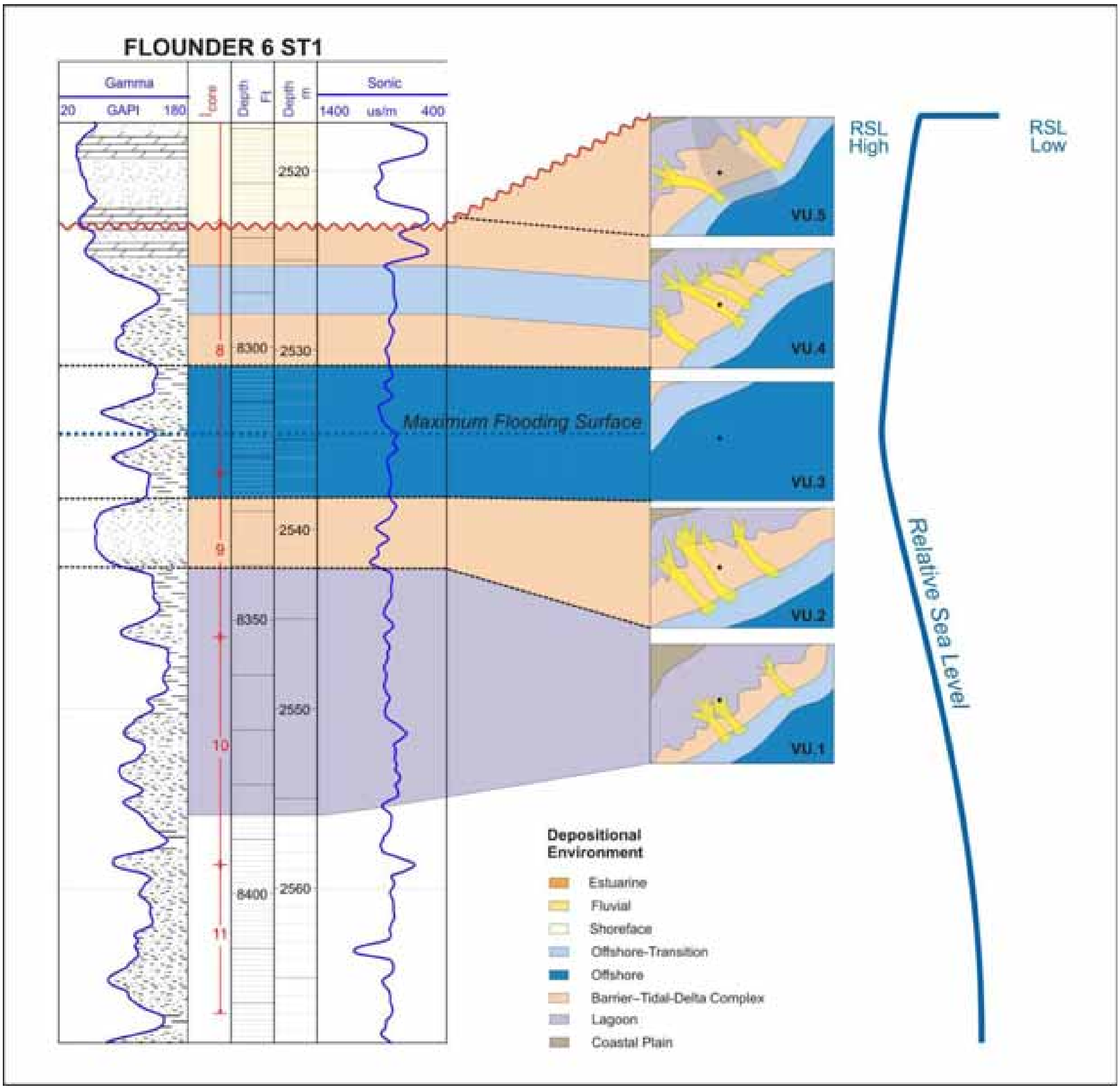


Figure 2.29. Upper Volador Formation. Palaeofacies maps and relative sea level curve. The black dot on the palaeofacies maps is the Flounder 6 location.
Please see *Appendix 2* for full size palaeofacies maps.

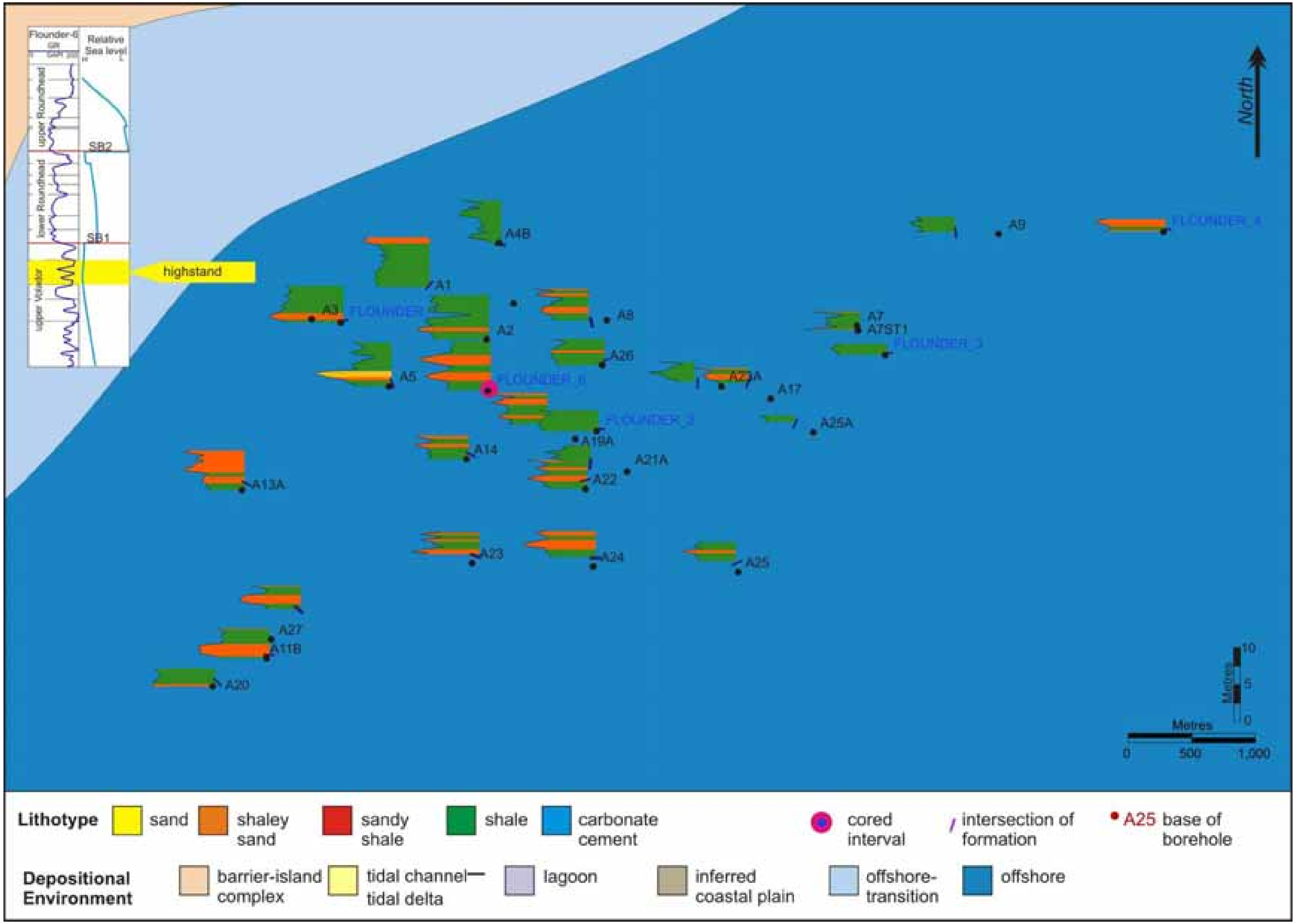


Figure 2.30. Log signature plot and palaeofacies map of the VU.3 unit. The barrier shoreface has transgressed across the field. This unit represents the maximum distance that the barrier transgresses, and is topped by the maximum flooding surface for this sequence.

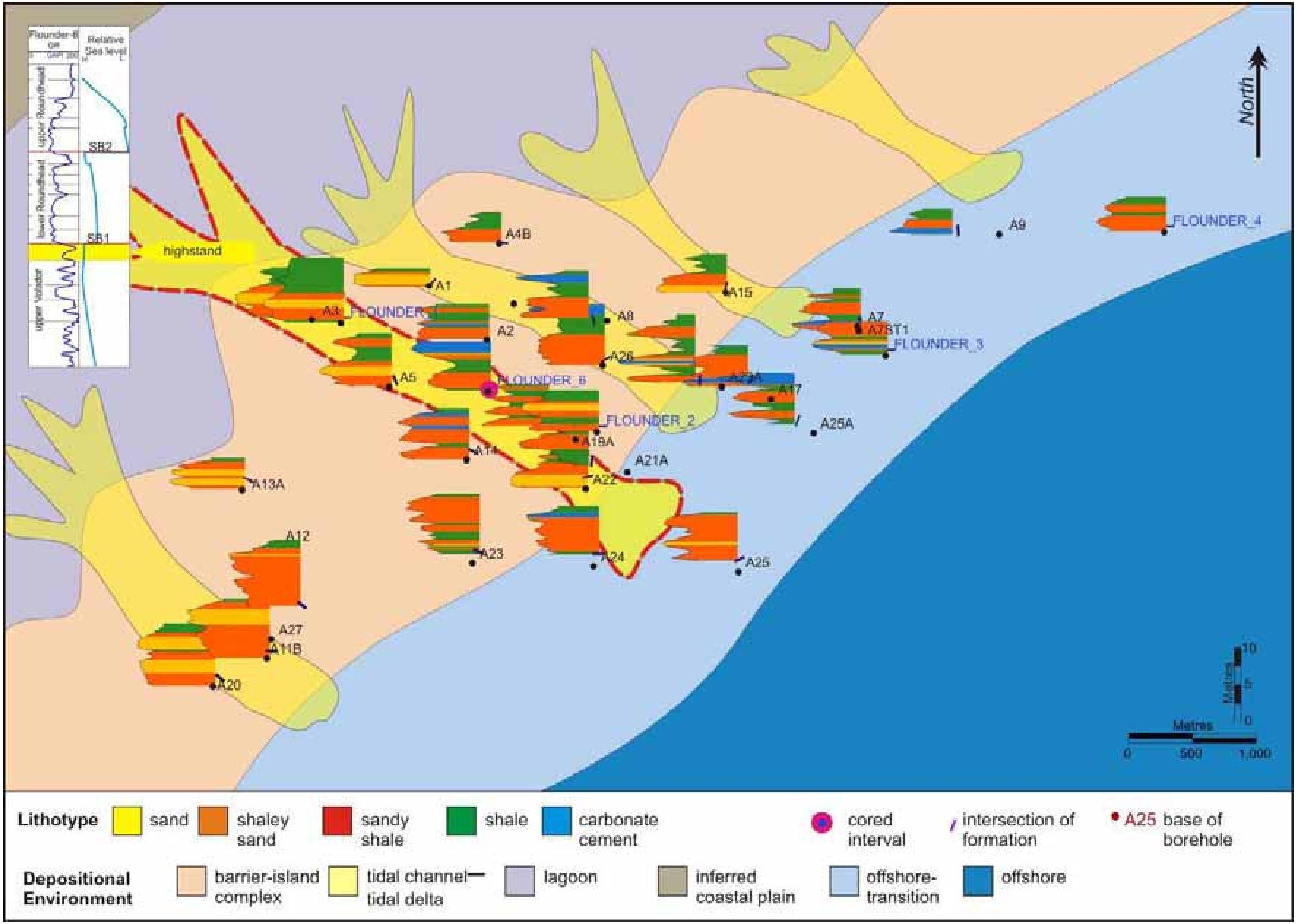


Figure 2.31. Log signature plot and palaeofacies map of the VU.4 unit. Note the blocky and fining-upward log signatures in the tidal inlet in the centre of the field (red outline) compared to the adjacent wells. (See <u>Appendix 2</u> for larger image).

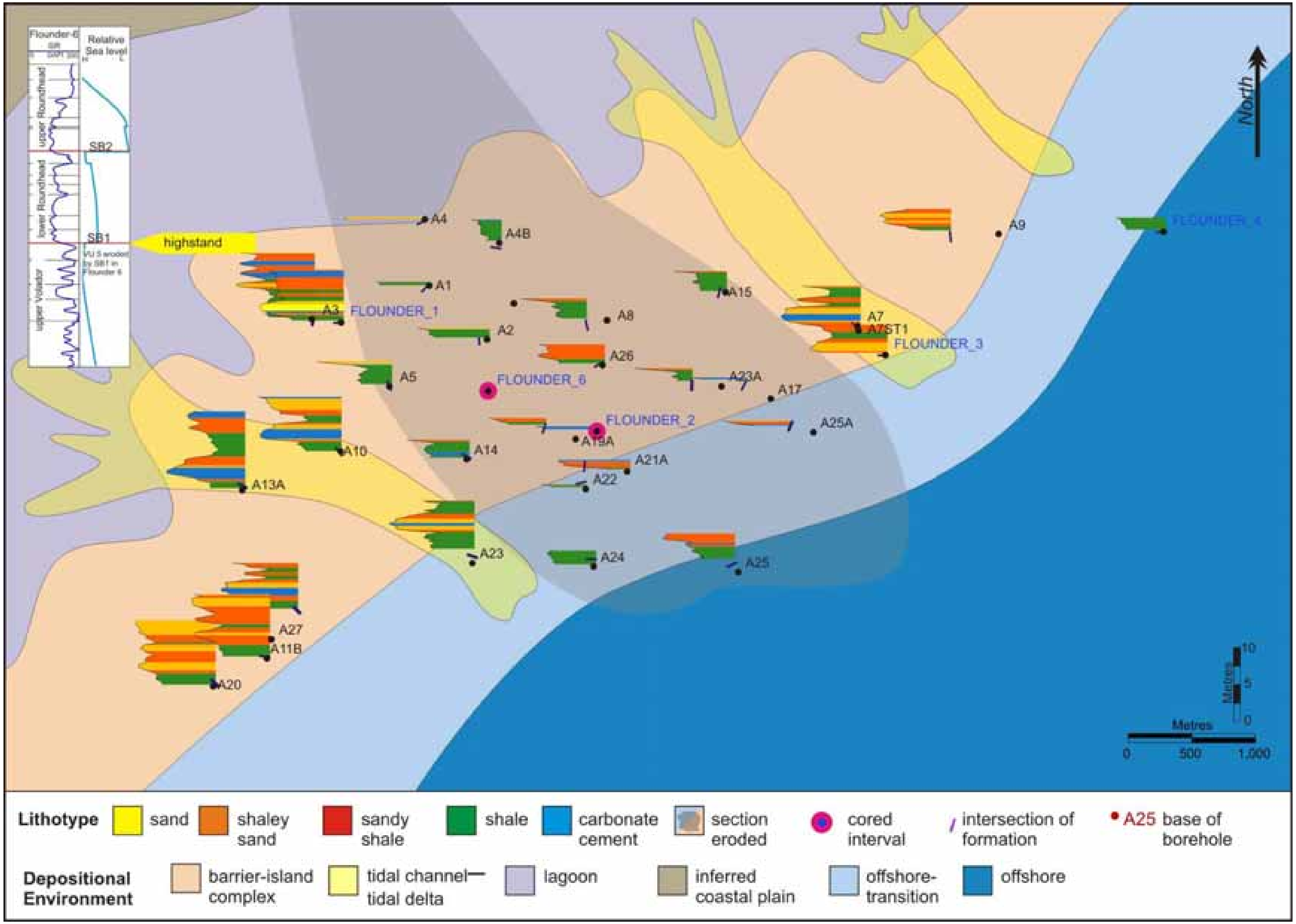


Figure 2.32. Log signature plot and palaeofacies map of the VU.5 unit. This interval is immediately below the SB1 boundary. Missing section is apparent in the middle of the field (grey tint). The shape of the missing section suggests that an incised valley may have removed the section. The overlying RL.1 unit (see Figure 2.34) consists of shoreface sediments that appears to fill the incised valley prior to covering all the field in the subsequent RL.2 unit.

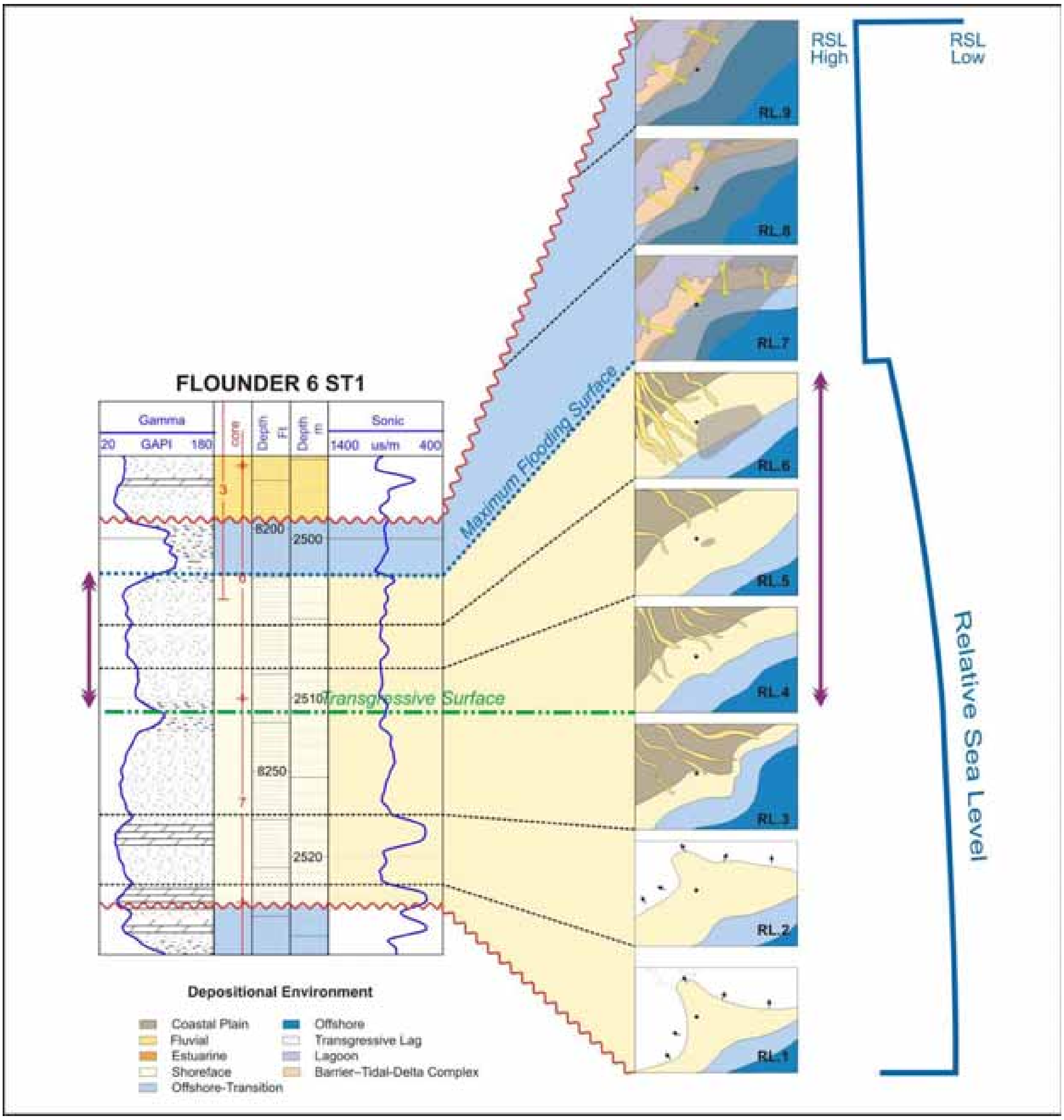


Figure 2.33. Lower Roundhead Member palaeofacies maps and relative sea level curve. This plot shows the palaeofacies depositional environment interpretation and relative sea-level curve for the lower Roundhead Member. This interval is dominated by shoreface sediments, inter-fingered with single story fluvial. Away for the core data, the distinction between shoreface and fluvial facies is made on the basis of the log signatures alone. The purple arrows highlight the RL.6 to RL.3 interval, over which the 3D modelling is carried out. The black dot on the palaeofacies maps indicates the location of Flounder 6.

Please see *Appendix 2* for full size palaeofacies maps.

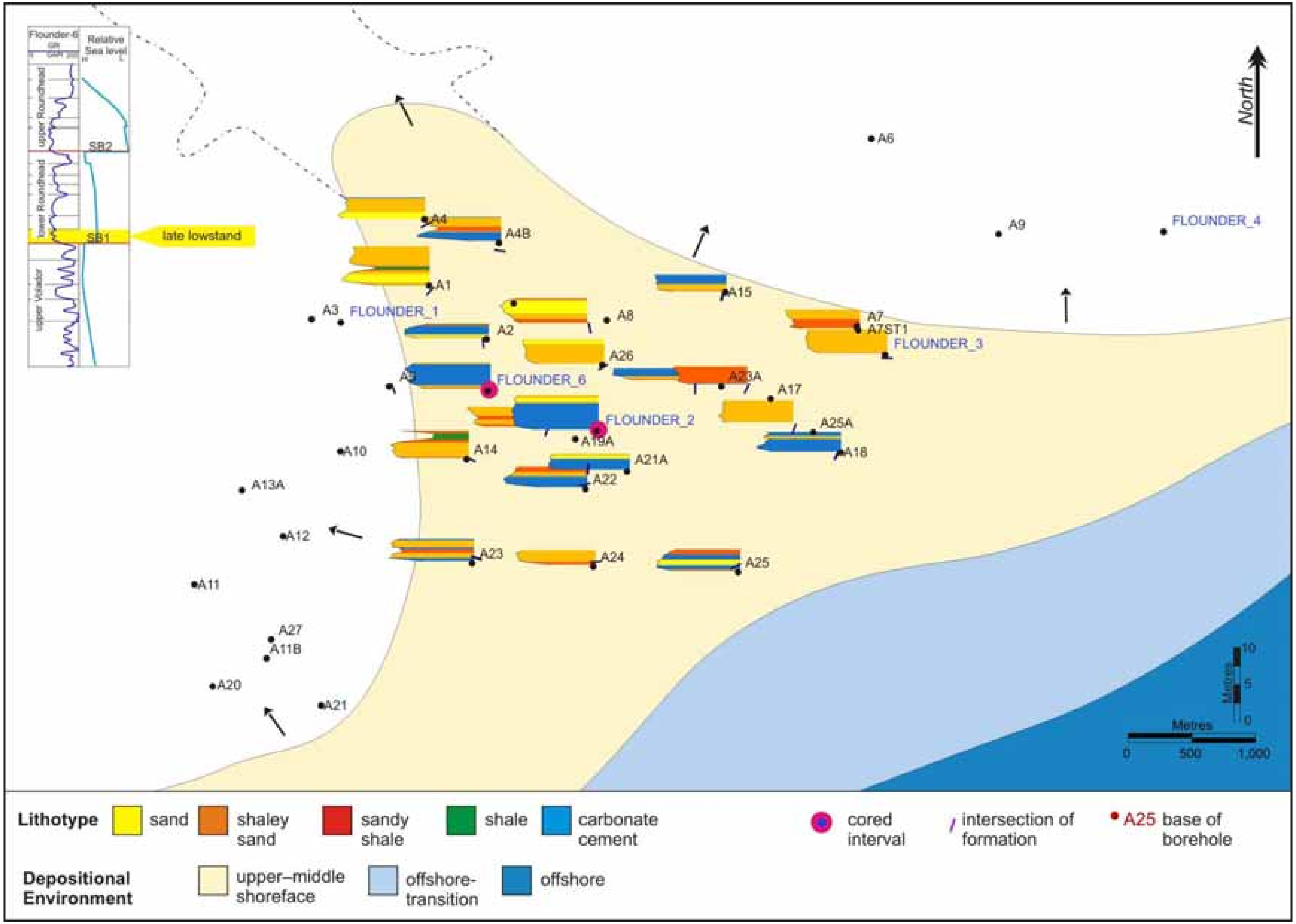


Figure 2.34. Log signature plot and palaeofacies map of the RI.1 unit.

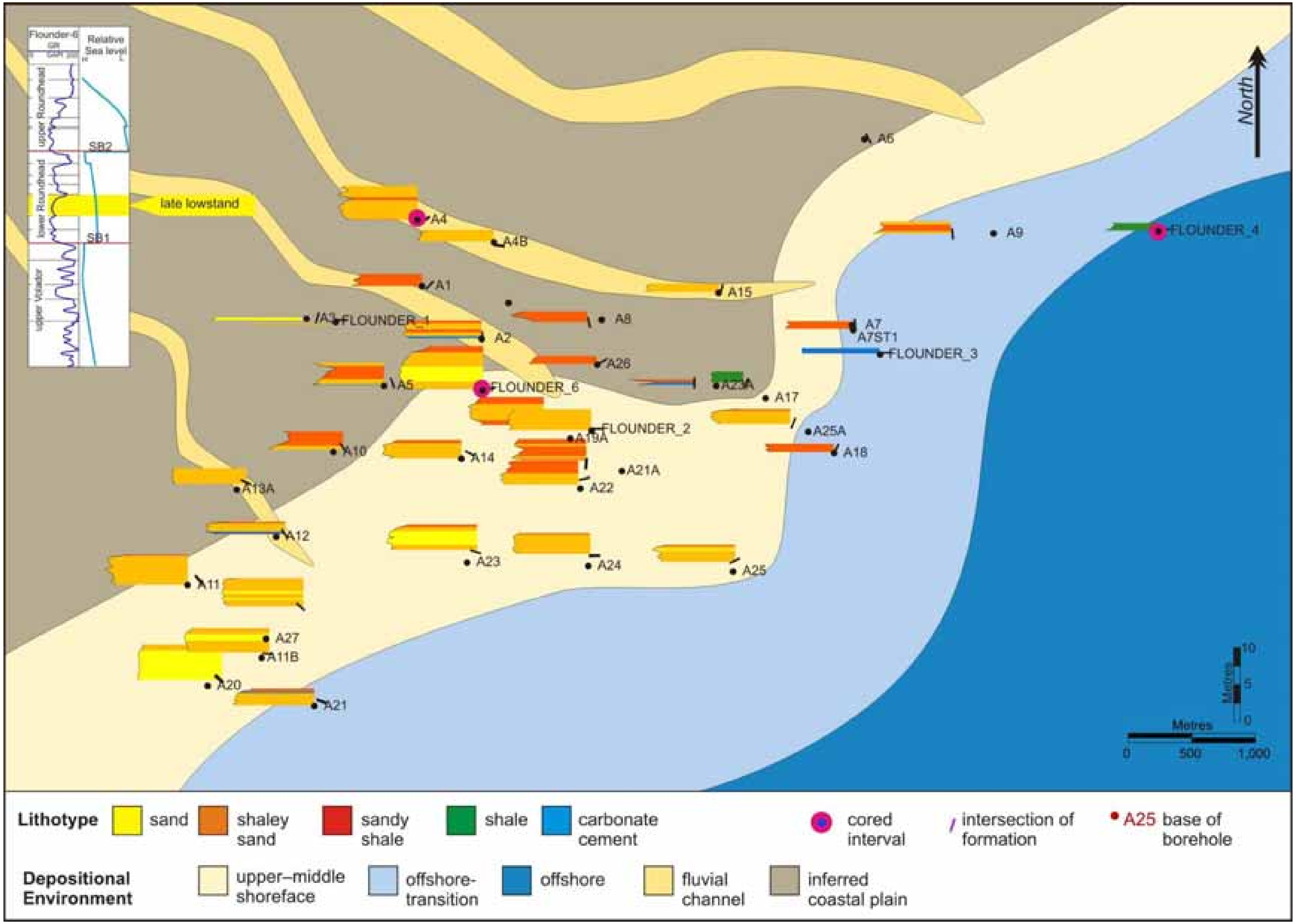


Figure 2.35. Log signature plot and palaeofacies map of the RL.3 unit. In this interval fluvial channels are seen in the north of the field for the first time.

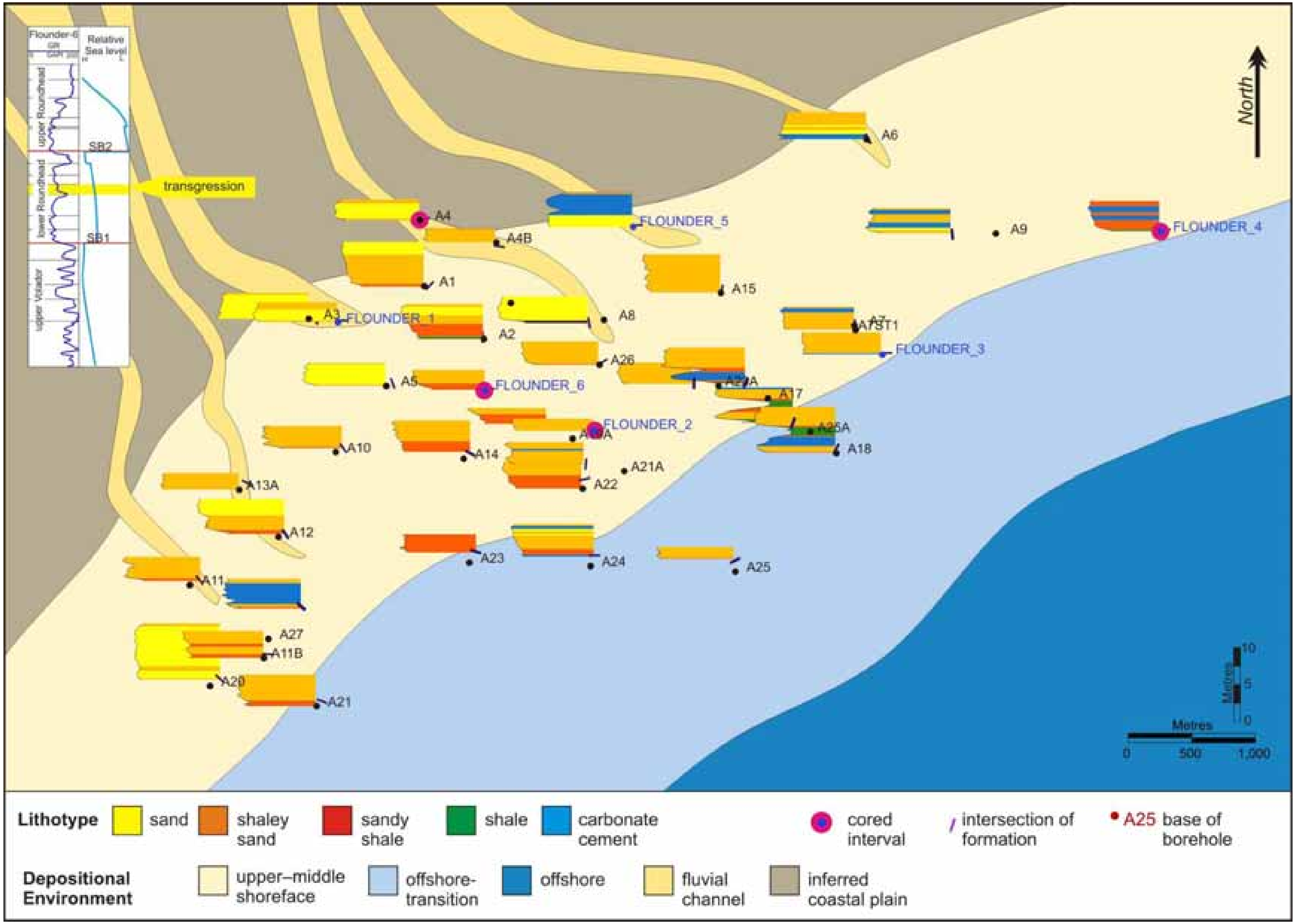


Figure 2.36. Log signature plot and palaeofacies map of the RL.4 unit. Away from cored intervals, channels are identified on the strandplain by an upward-fining log signature.

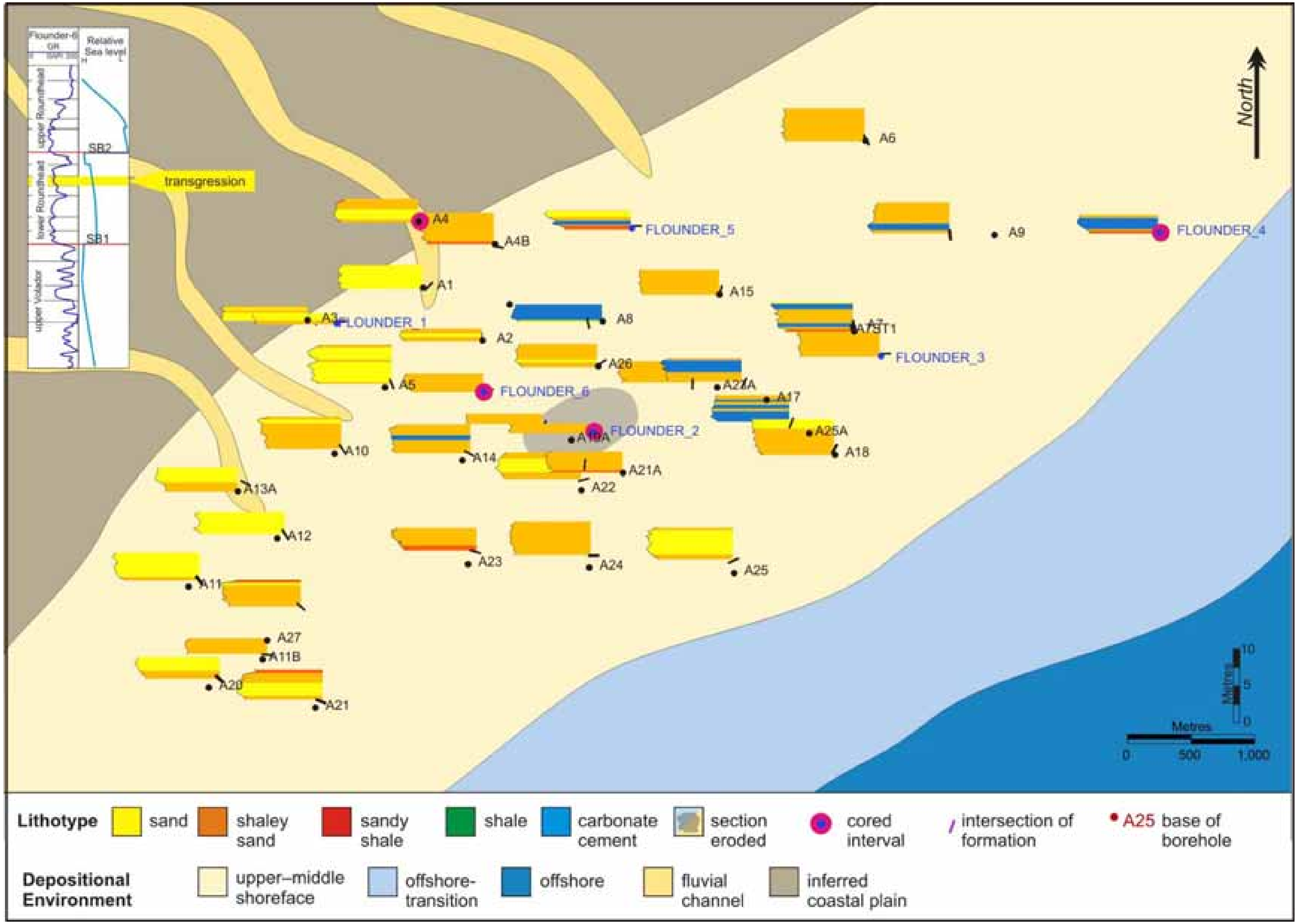


Figure 2.37. Log signature plot and palaeofacies map of RL.5 unit. At this level the upper/middle shoreface sediments cover the entire field and there appears to be little preservation of fluvial channels. Note the eroded section in Flounder 2 and A19. This is caused by the overlying SB2.

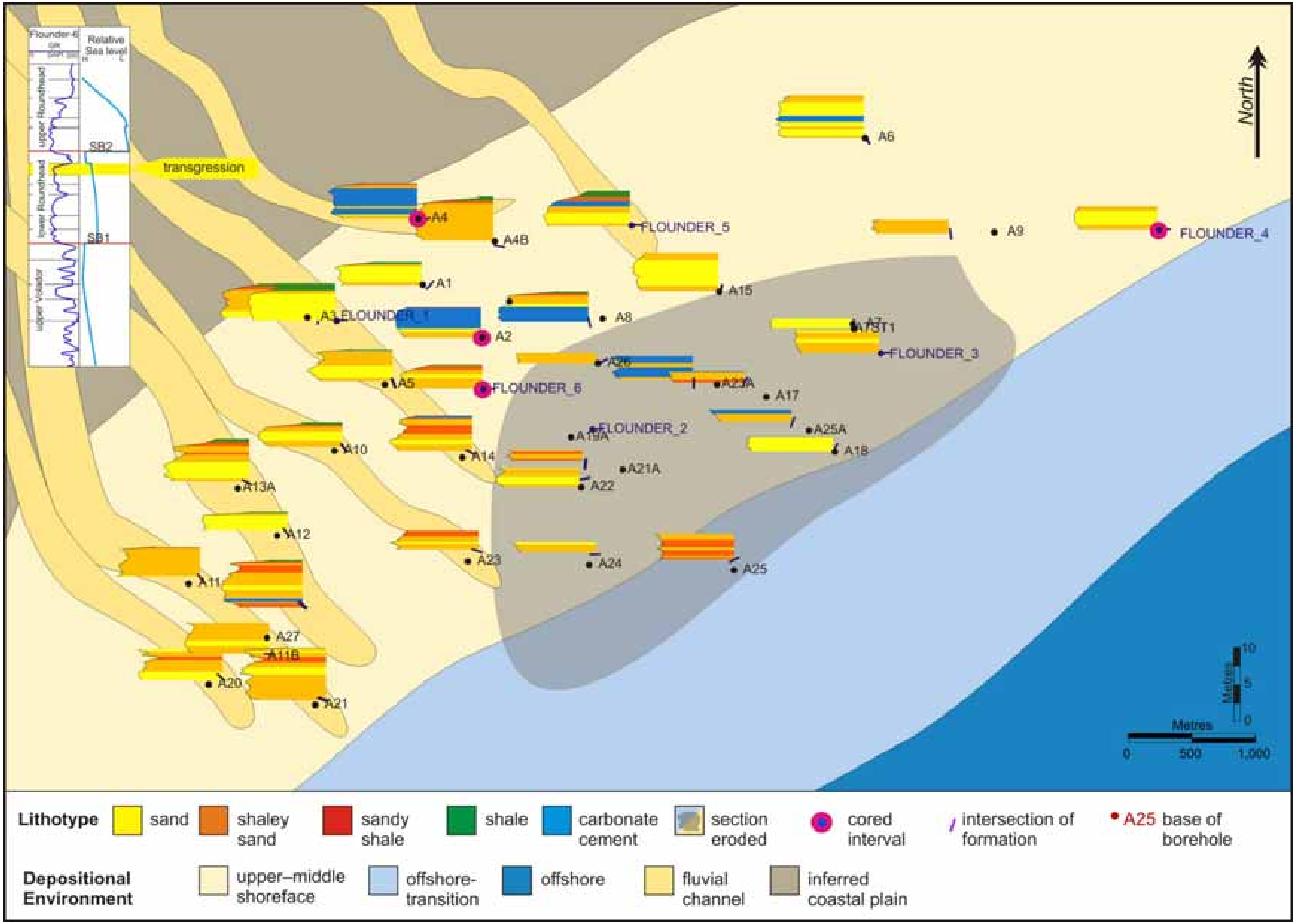
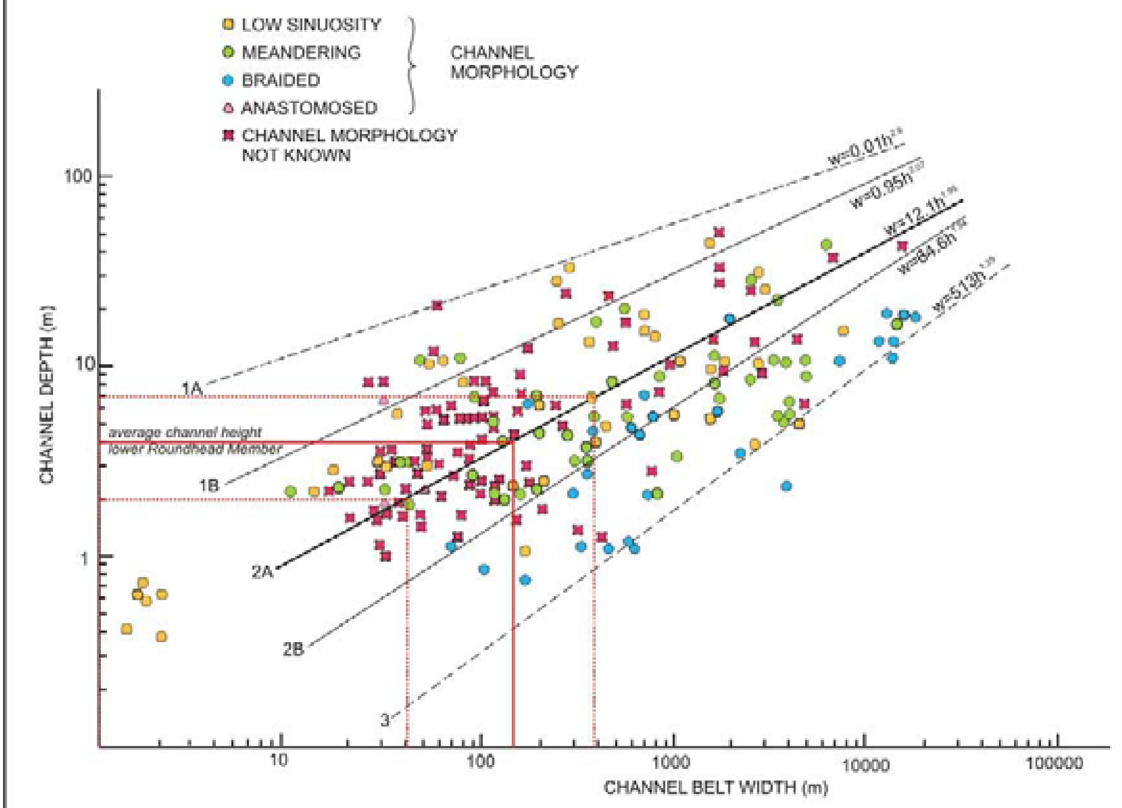


Figure 2.38. Log signature plot and palaeofacies map of RL.6. There is greater preservation of fluvial channels at this level compared to the underlying RL.5 unit. The erosion associated with SB2 is significantly greater in this interval (dark grey tint). This unit is missing in Flounder 2 and Flounder A19A.



Case 1A:the upper limit of all data collected (lowest width/depth ratio). Represents deposits of incised, straight and non-meandering channels.

Case 1B:the upper limit for meandering channel deposits. Meanders are restricted.

Case 2A: the best fit line for all data collected. May be used when a variey of channel types exists or channel type is not known.

Case 2B:the published empirical relationship for modern, truly meandering streams.

Case 3: the lower bounding line for data collected (highest width/depth ratio) - describes laterally unrestricted systems.

Figure 2.39. Channel thickness to channel belt with plot from Fielding and Crane (1987). This graph shows that the thin channels of the lower Roundhead Member are likely to be narrow. It is not directly applicable to the lower Roundhead Member as it does not include deltaic distributary channels, which are generally narrower than fluvial channels and less likely to create channel belts. The width:thickness ratio used is the best fit for all data. The lower Roundhead Member channels are too narrow to plot on the possibly more appropriate ratio line (case 1A) that represents incised straight and non-meandering channels.

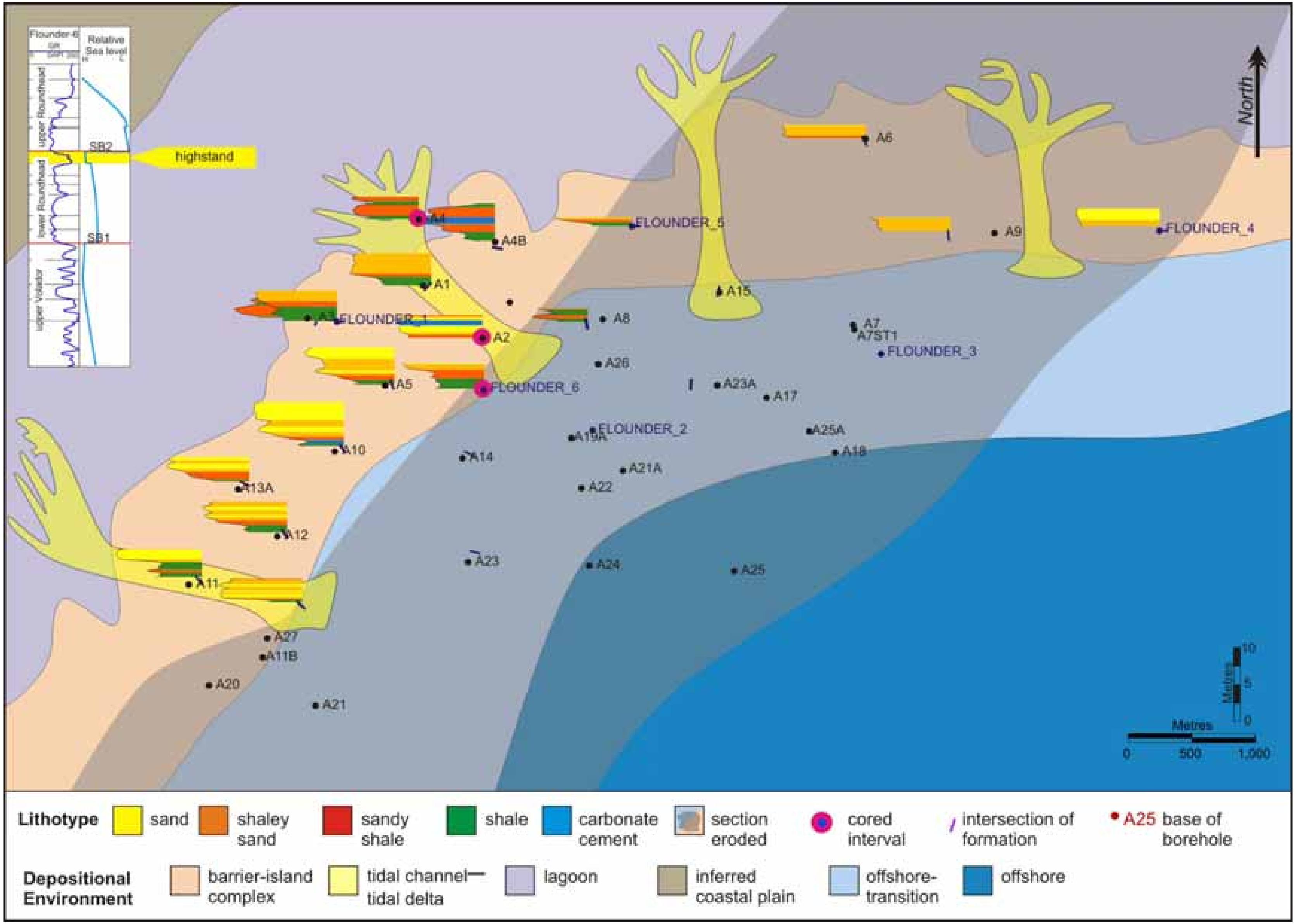


Figure 2.40. Log signature plot and palaeofacies map of the RL.7 unit. This unit represents a return to a barrier shoreface system. The core in Flounder A4 is interpreted to have been deposited in a restricted marine environment, while that in Flounder 6 is interpreted as open marine. As a consequence, the sand section in the wells between Flounder 6 and Flounder A4 is interpreted as barrier shoreface facies. Note also the large area of eroded section. This is associated with the overlying SB2. The eastern border of the incision is unknown, and has been given a linear boundary to suggest incision by an overlying incised valley that is in the order of 5–10 km wide.

NOTE:
This figure is included on page 81 of the print copy of the thesis held in the University of Adelaide Library.

Figure 2.41. Variance slice from the Northern Fields survey. The linear features to the northeast of Flounder 4 (orange) are interpreted as shoreline deposits. The shoreline features are not present over the Flounder Field as there was a fluvially-filled incised valley covering the field at this time. Image courtesy of J. Sayers (ASP).

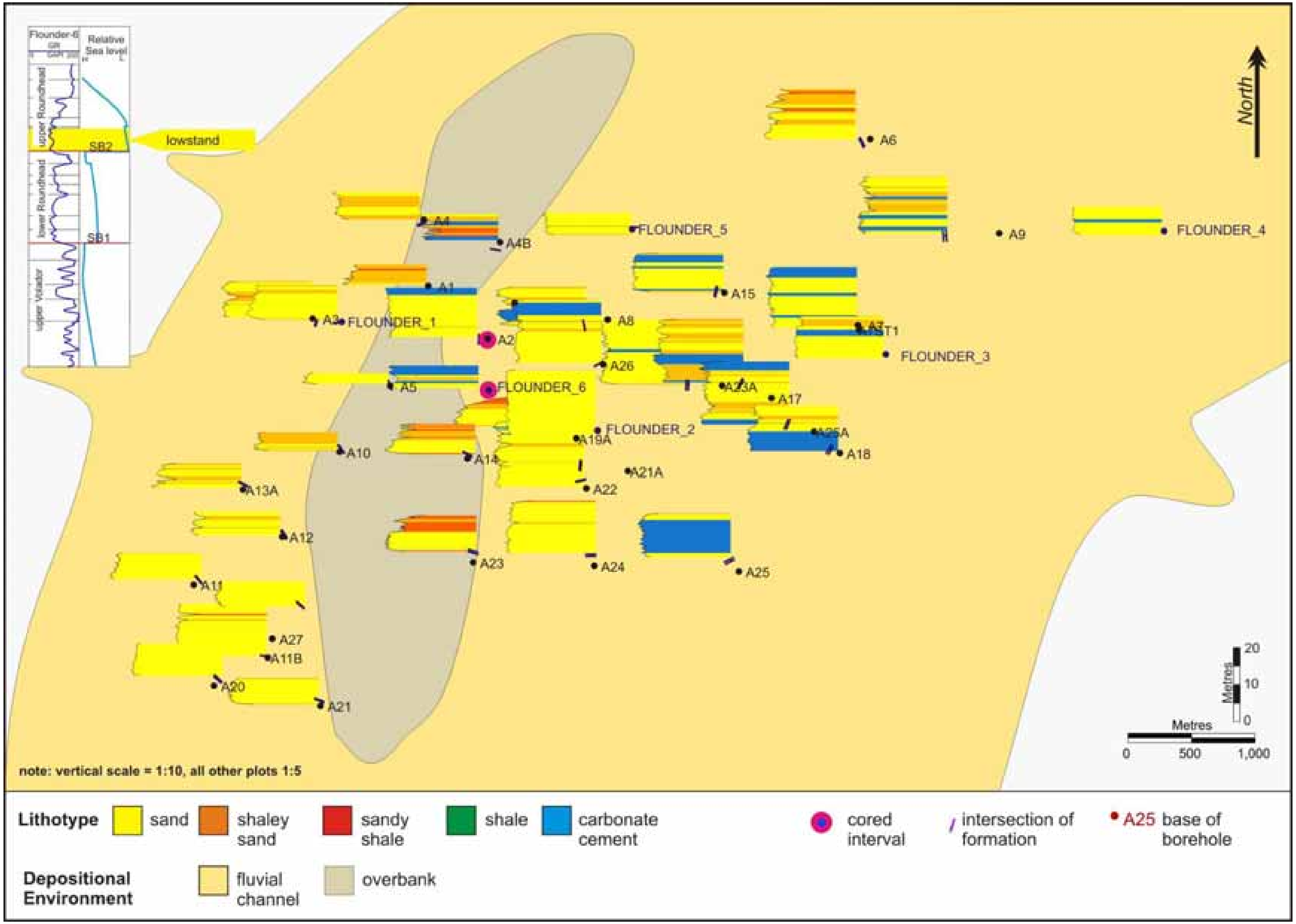


Figure 2.42. Log signature plot and palaeofacies map of the RU.1 unit. Fluvial deposits are interpreted to cover the entire Flounder Field.

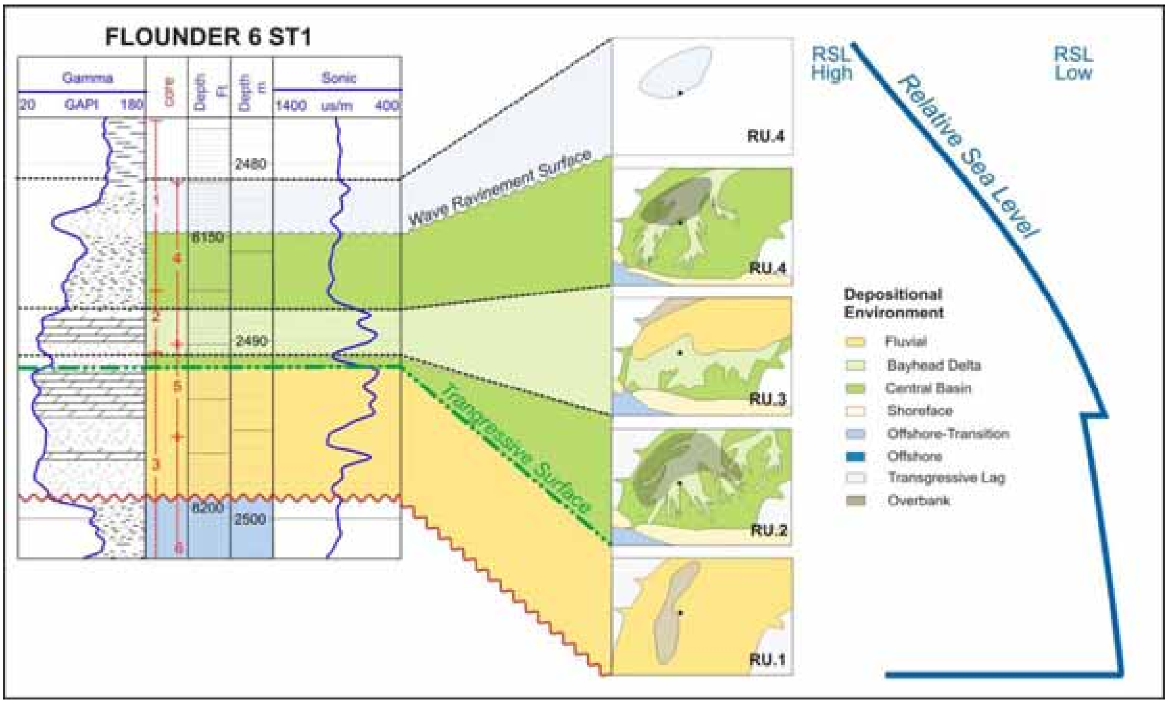


Figure 2.43. Upper Roundhead Member palaeofacies maps and relative sea level curve. The black dot on the palaeofacies maps is the Flounder 6 location. The incised valley of the Upper Roundhead is interpreted to have undergone two phases of fill. RU.1 represents the first late-lowstand to early transition fill which was followed by the more estuarine fill of RU.2. The interpretation of RU.2 depositional environment is based on the distribution of shale lithology and the overall higher shale content of the sands in this unit. The core in Flounder 6ST1 contains a mud drape in this interval. The RU.3 unit is the second phase of fill. The return to coarse sand in the majority of wells suggests that a relative sea-level drop has occurred. Although the log signature plot shows only a transgressive lag in the RU.4 interval, there is an estuarine component to this unit as well. In the Flounder 6 location the transgressive lag is a sharp-based sand overlying a bioturbated shaly-sand.

Please see _Appendix 2_ for full size palaeofacies maps.

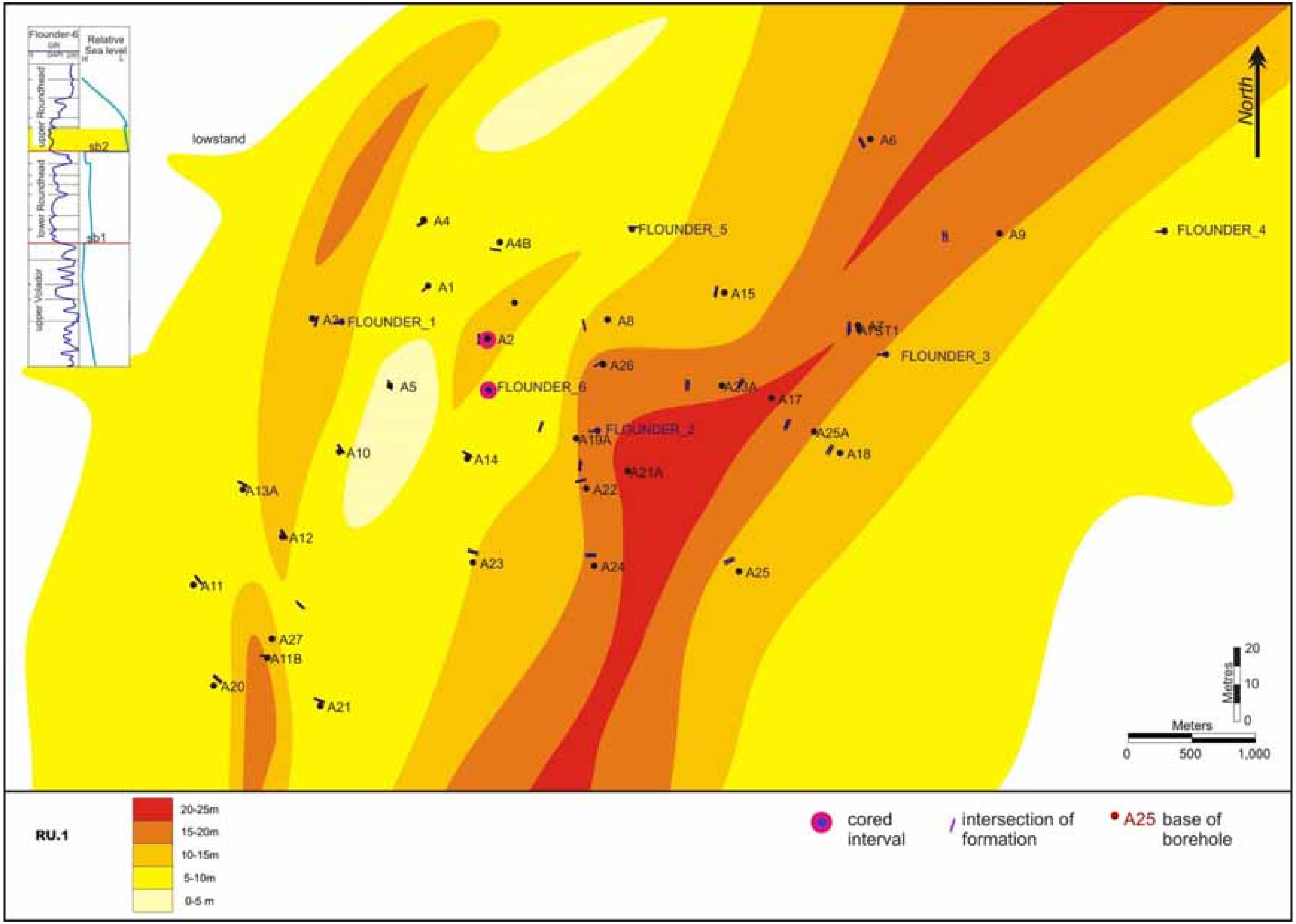


Figure 2.44. Upper Roundhead Member, RU.1 unit isopach. Note the main channel axis on the right side of the field and the second, lesser fairway on the left. The thickest section overlies the thinnest (most eroded) lower Roundhead Member section.

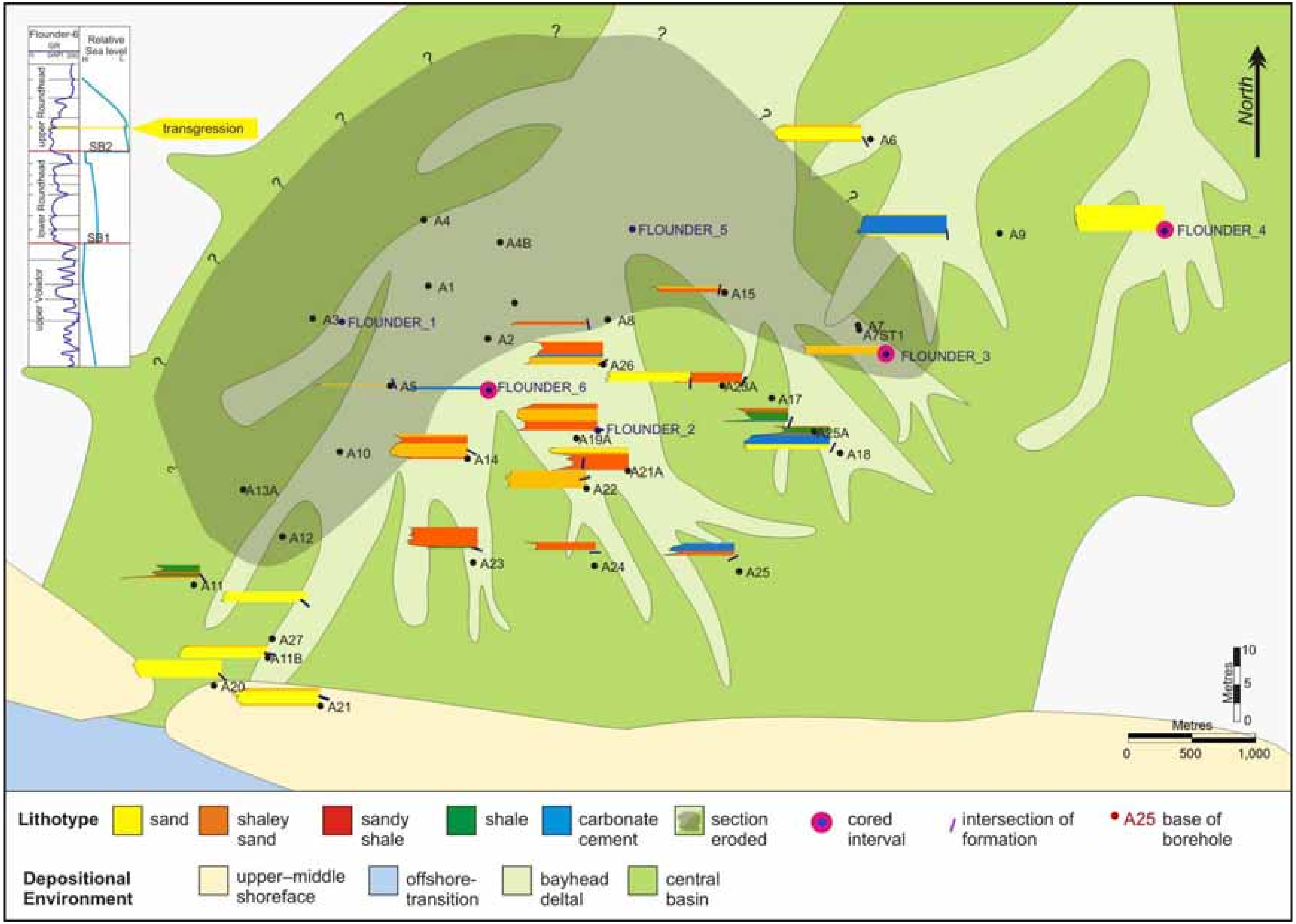


Figure 2.45. Log signature and palaeofacies map of the RU.2 unit. Transgression has resulted in the deposition of estuarine sediments. A bayhead delta, filling a central basin, which is separated from the open marine environment by a barrier shoreface is postulated.

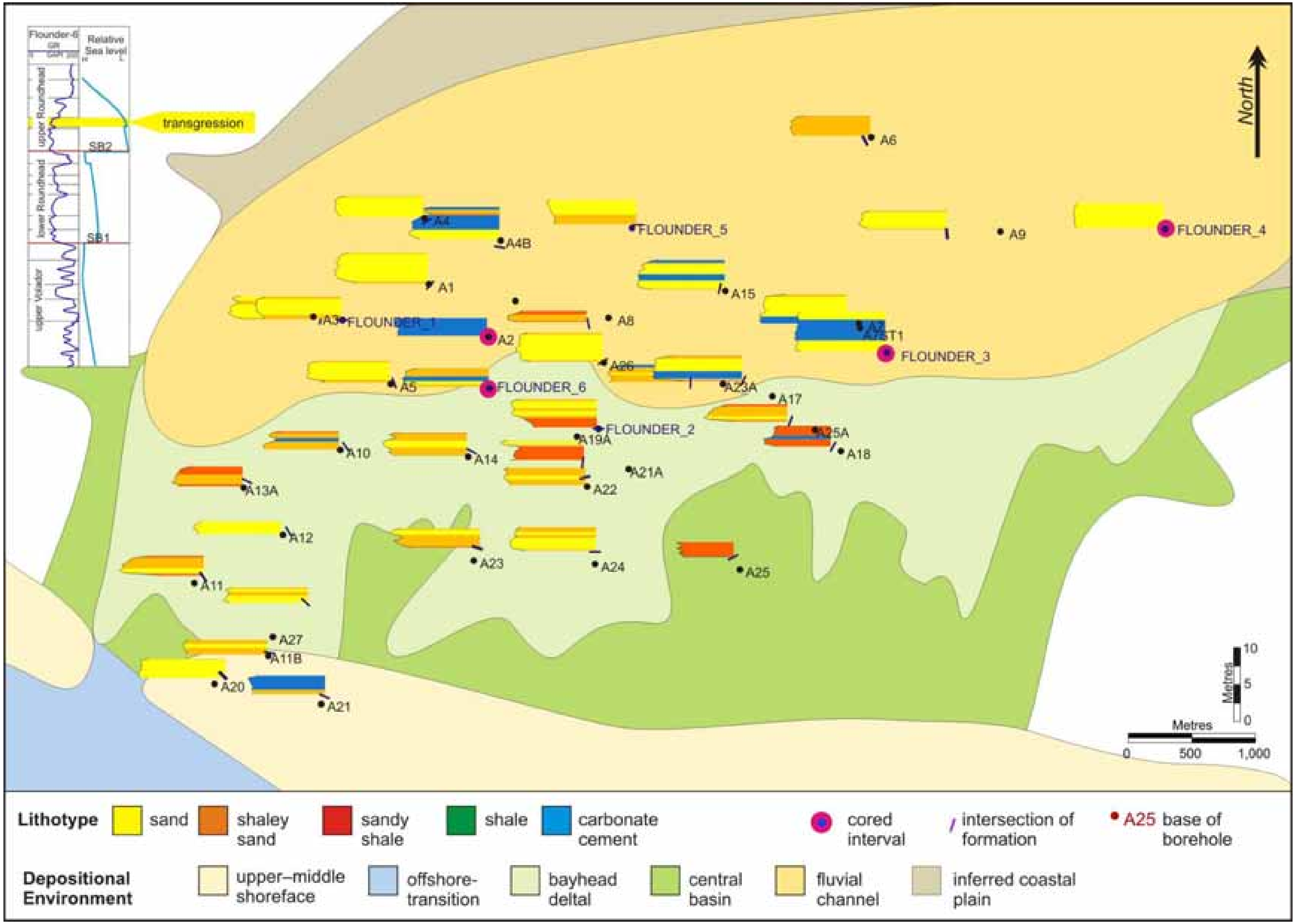


Figure 2.46. Log signature and palaeofacies map of RU.3 unit. The cores in Flounder 6 and Flounder A2 show estuarine characteristics, while the cores in Flounder 3 and 4 appear to be fluvial in origin. The blocky log signatures also indicate a fluvial influence in the north of the field.

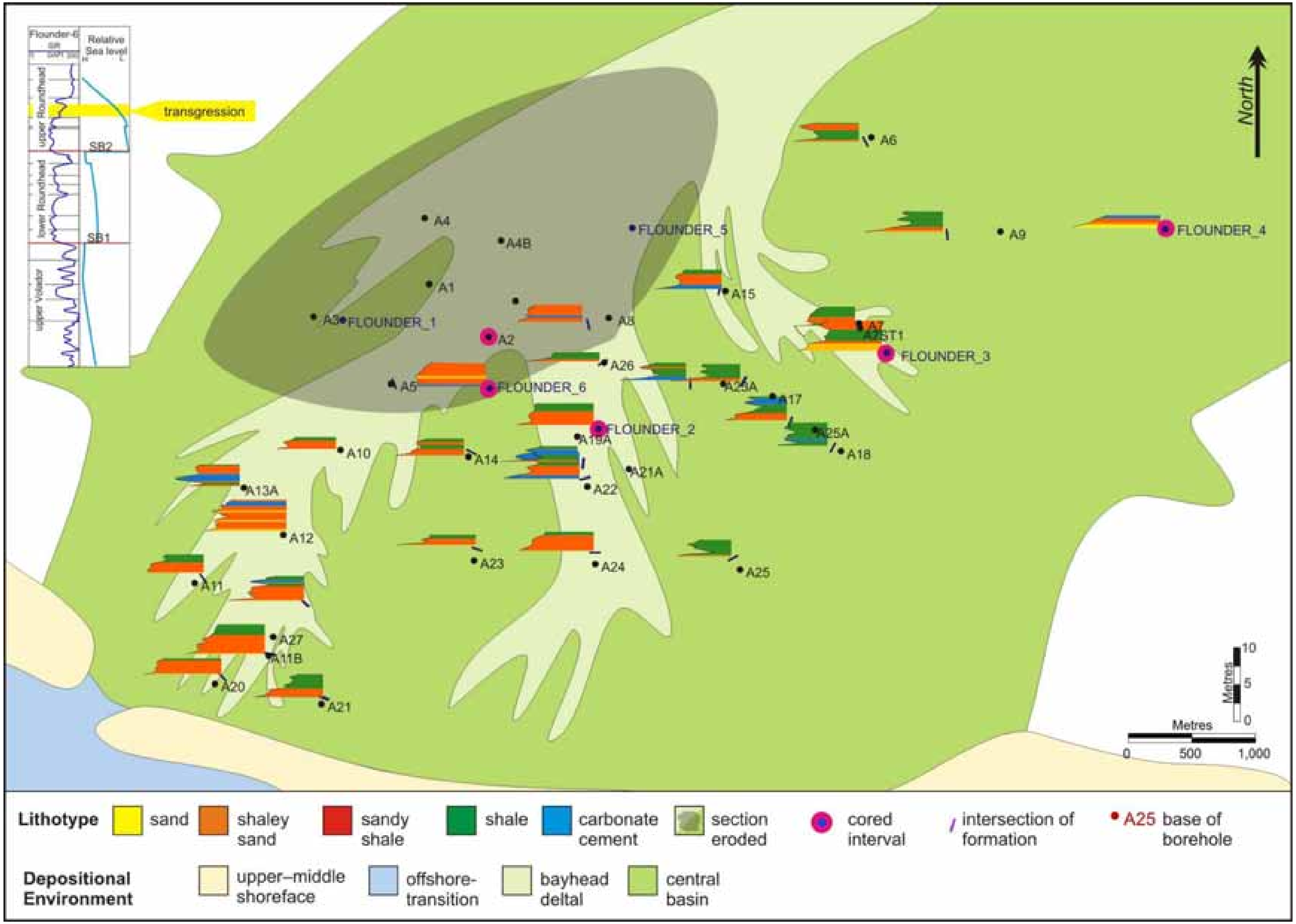


Figure 2.47. Log signature and palaeofacies map of the lower RU.4 unit. The cores in Flounder 3, 4 and 6 show estuarine characteristics, but have no tidal beds.

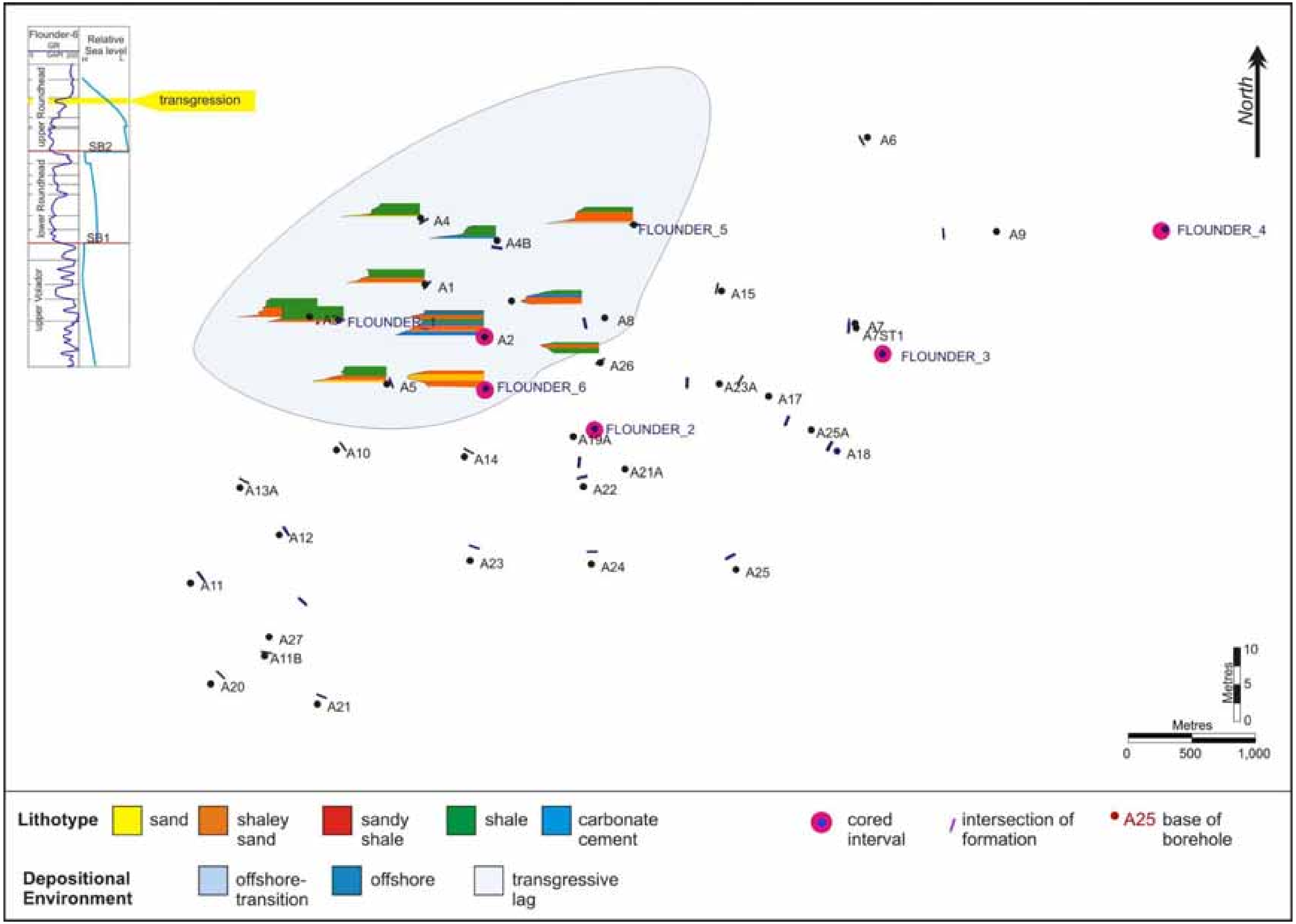


Figure 2.48. Log signature plot and palaeofacies map of the upper RU.4 unit. Core in Flounder A2 indicates a shoreface was present at that location at this time. It is interpreted that the shoreface is the remnants of the transgressive shoreface. The other wells in the area are interpreted as transgressive lag as well because they have a smoother fining-upward profile than other wells. It was preserved at Flounder A2 as the shoreface may have filled a low area associated with the erosion of the underlying RU.2 unit in this area.

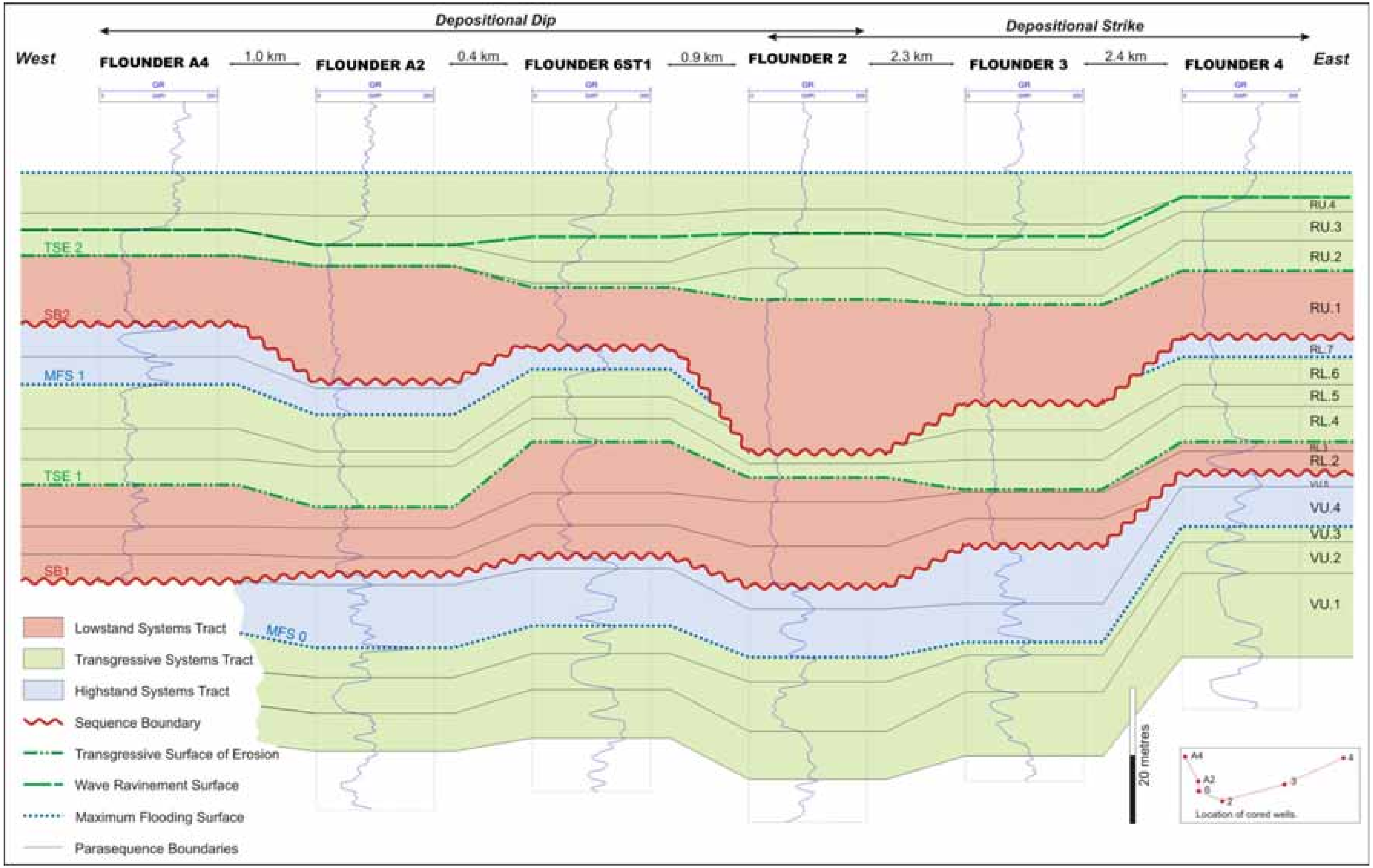


Figure 2.49. Systems tracts in the Flounder Field. This diagram highlights the dominance of transgressive deposits in the geological record in the Flounder Field. While the units interpreted in the lower and upper Roundhead Member conform to the definition of parasequences, the interpretation in the upper Volador Formation is not as detailed and the units may encompass more than one parasequence.