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FACIES ANALYSIS AND RESERVOIR GEOMETRY OF THE CRYSTAL VIKING FIELD, Tp. 45 and 46, Rg. 3 and 4W5, CENTRAL ALBERTA

by
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ABSTRACT

The Viking Formation in the Crystal field contains a linear sandstone-conglomerate deposit which attains thicknesses of 30 m and is aligned in a north-south direction. The thickness and alignment trends of this reservoir 'sand' body contrast sharply with other established Viking sandstone reservoirs, which are generally much thinner and oriented more in a northwest-southeast direction. Another contrasting feature of Crystal compared to other Viking oil fields, is that the producing reservoir consists of two distinct, hydrodynamically-separated oil pools ('A' and 'H' pool). The Crystal Viking 'A' pool contains ninety-six per cent of the estimated recoverable reserves of $5.8 \times 10^6 m^3$, with the 'H' pool being situated higher stratigraphically, and partially overlapping the main producing zone on the western side.

Two major facies constitute the Viking Formation at Crystal, channel and estuary-bay fill. The combined association of the two facies represents an estuarine tidal channel-bay complex. Detailed log and core correlations indicate that: 1) the estuarine channel-bay complex is unconformable with underlying and adjacent innner shelf-lower shoreface deposits of the regional Viking facies and; 2) the linear reservoir sand body consists of four depositional units; the lower three units are representative of successsive and partially-superimposed channel-fill stages (A, B, C), and the uppermost unit (H) is a shallow channel-bar deposit representative of the final episode of estuary bay-fill deposition. The multistage channel depositional events are interpreted to be the record of progressive estuarine valley fill under conditions of rising sea level, with each channel depositional stage corresponding to a stillstand during an overall transgressive period. Each channel stage modified the estuary on the eastern side while subtidal estuary-fill muddy deposits accumulated as facies equivalents to the channel-fill deposits, on the western side. The superimposed channel-fill deposits (A, B, C), constitute the bulk of the reservoir and form the Crystal Viking 'A' pool, whereas the shallow channel-bar deposits (H) constitute the much smaller producing zone of the Crystal Viking 'H' pool.

The occurrence of two separate pools, and the variability in reservoir capacity, continuity and performance trends of the 'A' pool, are controlled directly by depositional factors. The depositional model of progressive estuarine valley fill under transgressive conditions readily explains the presence of the 'H' pool as a discrete reservoir separated from the main oil-bearing 'A' zone pool. The highly productive wells of the 'A' pool correspond to specific channel stage deposits, or are situated in the areas where channel deposits of successive stages are highly superimposed. In contrast, marginally productive wells and poor reservoir communication between producing wells, occur in the areas where the different channel-stage deposits are shown to diverge. Given the observed relationship between depositional trends and overall reservoir behavior, it is apparent that facies distribution and channel-stage geometries must be considered during both the planning and evaluation phases of any secondary recovery scheme.

ACKNOWLEDGMENTS

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INTRODUCTION

Study area

The Cystal Viking Field is situated in Tps. 45 and 46, Rgs. 3 and 4W5, some 25 km north and 80 km west, of the Gilby-Bentley and Joarcam Viking oil-producing trends respectively (Fig. 1). The Crystal field is the most recent significant Viking oil find, having been discovered in the fall of 1978. The original discovery well (6-7-46-3W5) encountered a thick, but apparently low-porosity sand interval which was not tested or cored, but thought to be gas-bearing as other previous wells in the area. The 6-7 well was cased for later completion as a gas well. In early 1979 a subsequent well (3-8-46-3W5), situated on the eastern side of the present field (Fig. 2), yielded 400 m of oil on drill-stem testing, and was completed as an oil well. This prompted a second 'look' at the 6-7 well, and it was subsequently completed, also as a producing oil well. The next well to be drilled was in 1981 at location 13-5-46-3W5, on the eastern limit of the present field. This well also yielded oil, and development drilling began in earnest in 1981. The result is a fairly substantial producing field with estimated recoverable reserves totalling $5.8 \times 10^6 m^3$ from two separate pools, 'A' and 'H' pool (Fig. 2). Ninety-six percent of these recoverable reserves are contained within the 'A' pool.

The Crystal field is rather unique compared to older established Viking oil fields such as Joffre, Gilby-Bentley and Provost (Love, 1955, 1960; Koldijk, 1976; Lerand and Thompson, 1976; Alho et al., 1977), in that the reservoir sand body is over 30 m thick and elongated in a north-south direction (Fig. 3). The other Viking oil fields are elongated either northwest-southeast or west northwest-east southeast and cover much larger areas, with reservoir zones being in the order of 5 m thick, or less.

Another unique feature of Crystal relative to other Viking oil-bearing fields is the occurrence of two separate oil pools, each with their own gas cap, situated adjacent to, and partially overlapping one another (figs. 4, 5). Gas of the 'H' pool is

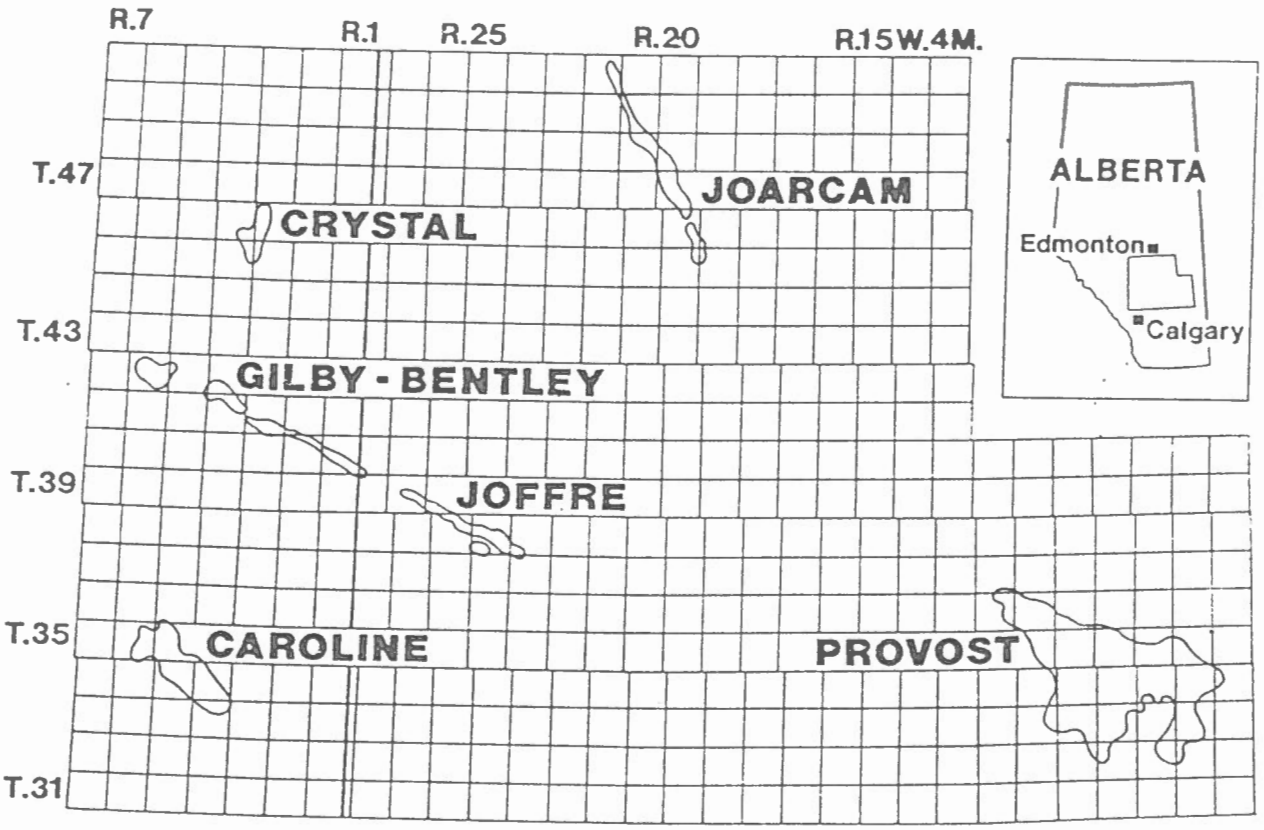

Figure 1. *Location of the Crystal Field relative to other Viking oil fields in south-central Alberta.*

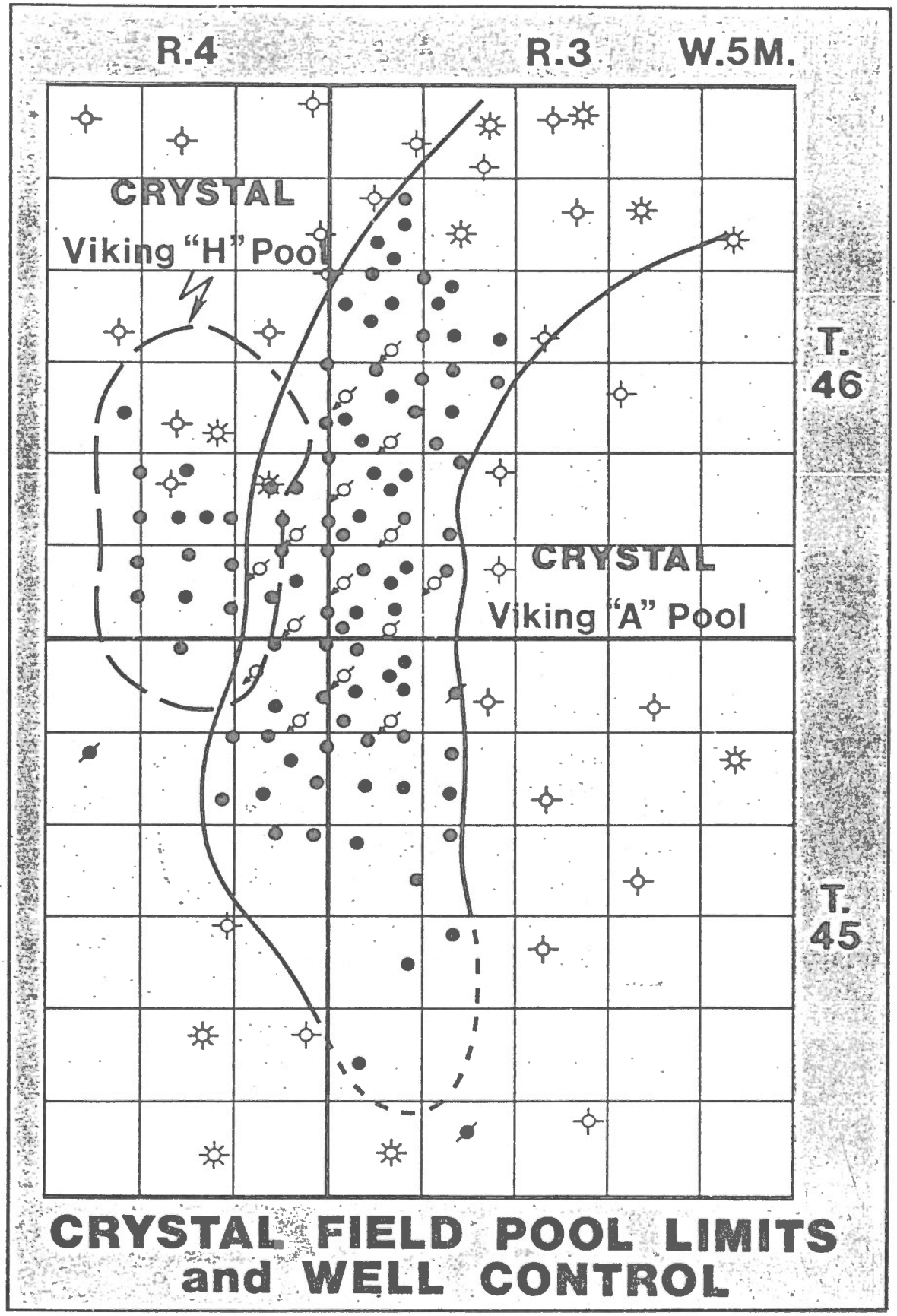

Figure 2. Crystal field – pool limits and well control.

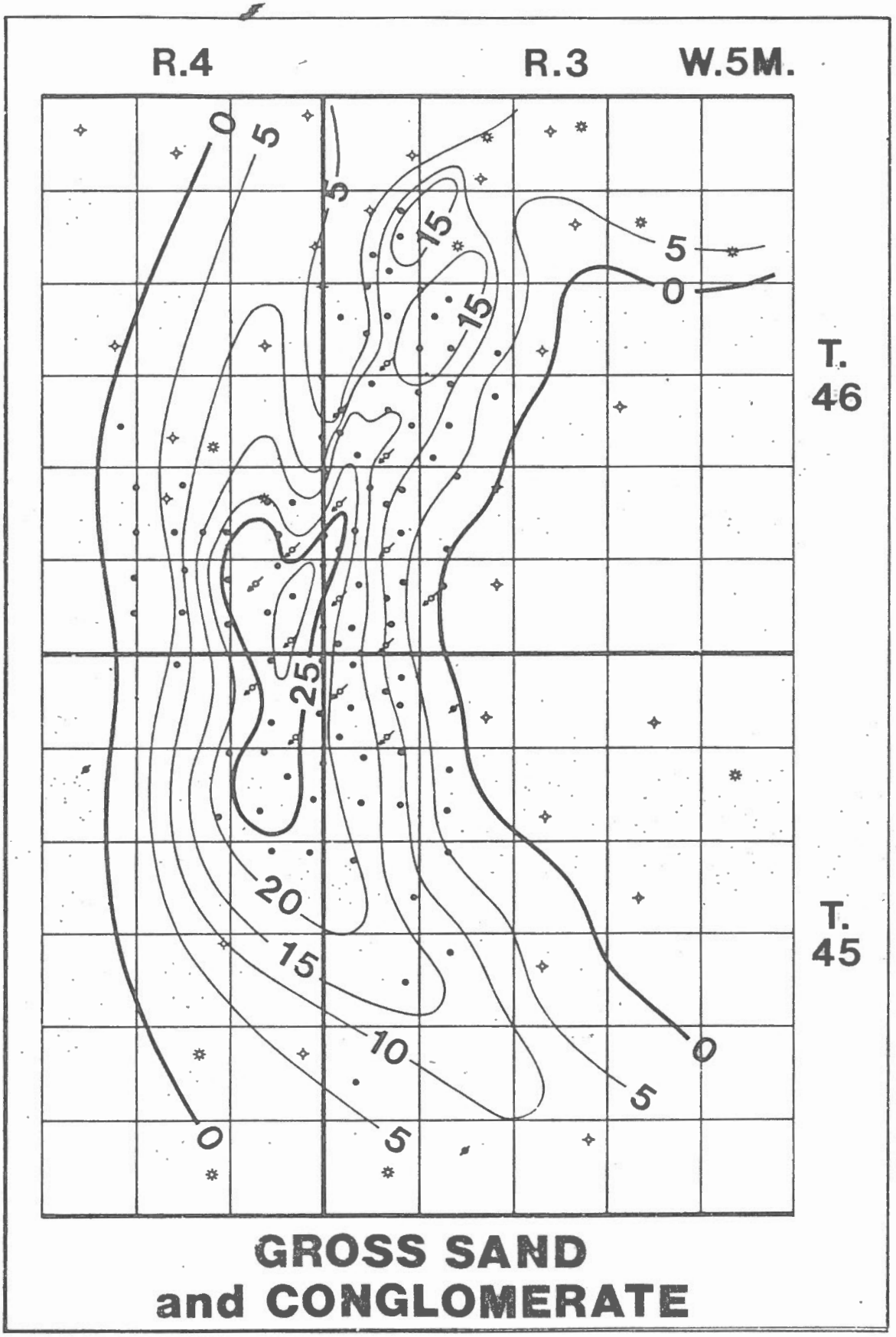

Figure 3. *Isopach map of total thickness of sandstone plus conglomerate lithofacies (gross pay map). (Isopach line interval – 5 m.)*

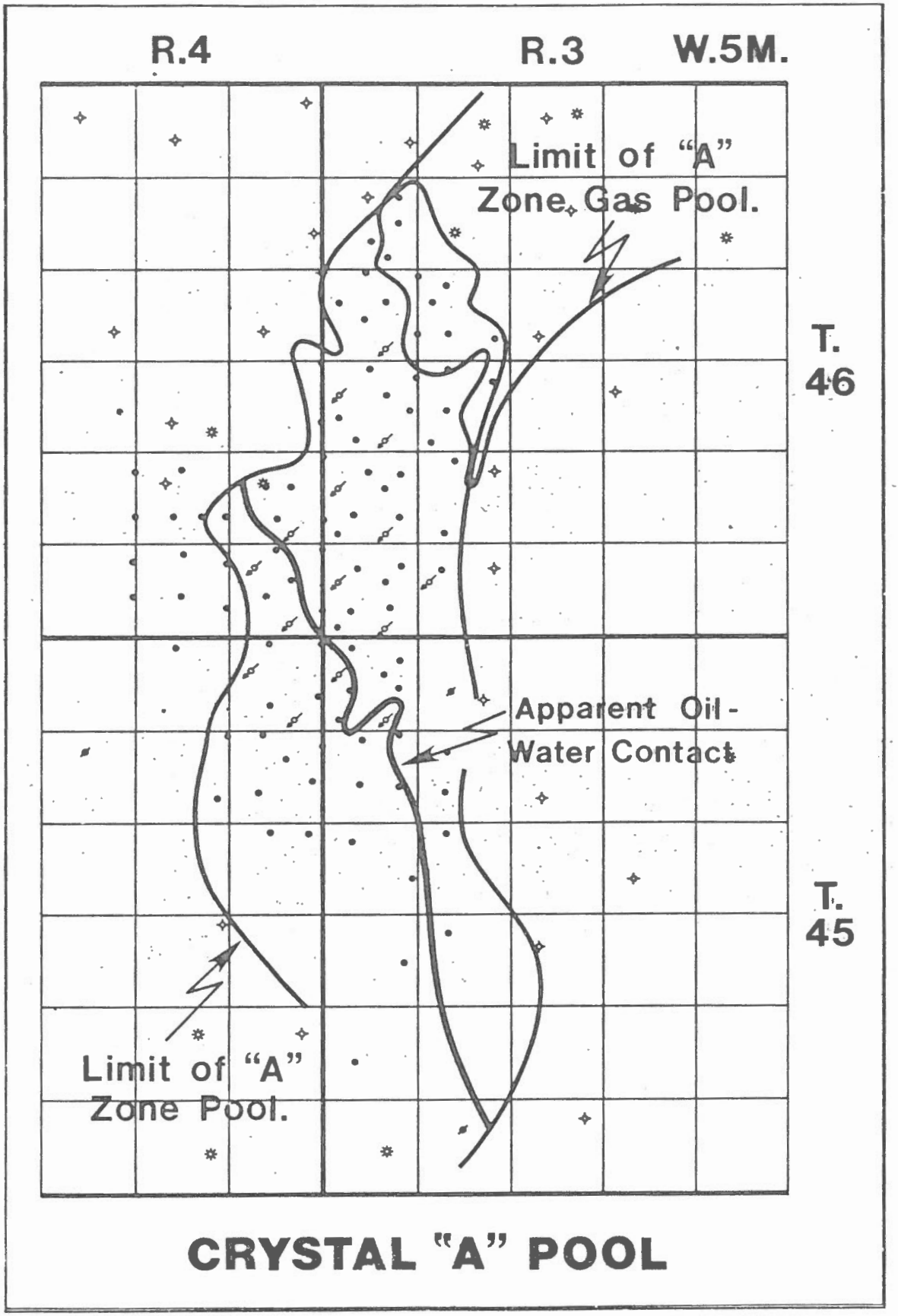

Figure 4. Map of the Crystal Viking 'A' zone pool showing the positions of the gas/oil and oil/water contacts.

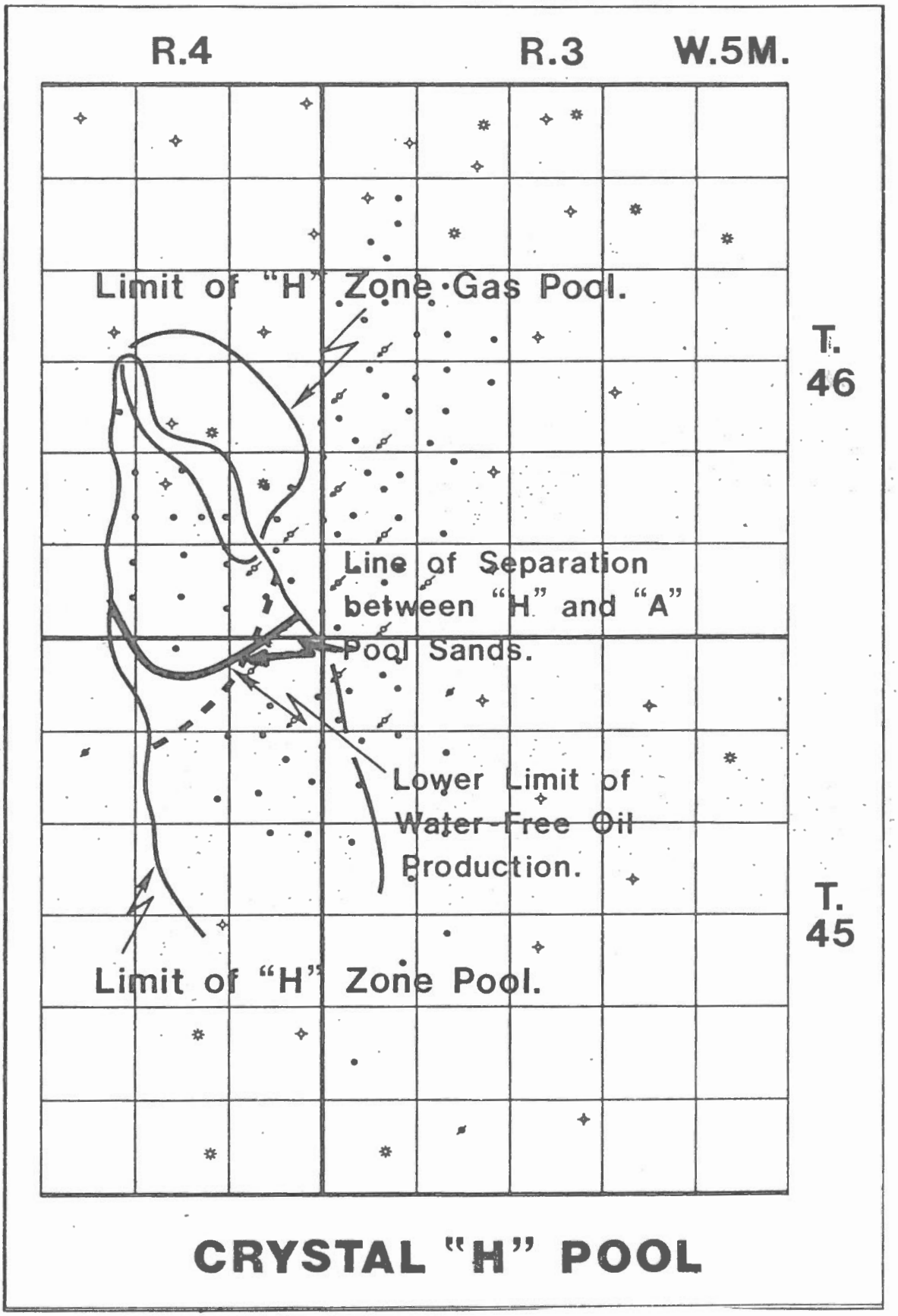

Figure 5. Map of the Crystal Viking 'H' zone pool showing the positions of the gas/oil and oil/water contacts, and the approximate position at which 'H' pool sandstone becomes separated from underlying 'A' pool sandstone.

situated structurally lower than oil of the 'A' pool, and this is an unusual situation in sandstone stratigraphic traps of this type.

Objectives

The objectives of this study were as follows: 1) to develop a sedimentological model of the facies geometry and depositional environment of the Crystal Viking Formation through detailed microfacies sequence identification and correlation and, 2) to evaluate this model with respect to depositional controls on continuity, and internal geometry of the producing reservoir zone. A further objective presently being considered in concert with Westcoast Petroleum Ltd., is the utilization of this facies mapping study for assessing the primary recovery trends of the producing reservoir, and for evaluating any secondary recovery schemes presently being planned or in progress.

Method and data base

An extensive, high-quality, log and core data-base exists on the Crystal Viking field. This is due both to the recent discovery and development, and the unique reservoir complexities, of Crystal relative to other Viking oil fields. Cores are available from almost all of the wells within the field, along with corresponding conventional core-analysis data (Ø, K, Sw, Sor). A suite of high-quality geophysical logs (sonic, density, electrical) is also available for all wells.

Core and mechanical logs from 140 wells were utilized during the course of this study. In this type of geological study it is necessary to examine well data adjacent to the Crystal pool boundaries, as well as within them. Some 110 of these wells lie within either the 'A' or 'H' pool boundaries.

A total of 74 well cores were described in detail in litholog format (Appendix I), enabling the graphic delineation of vertical facies sequences and depositional stages. The facies sequences in cores were compared with the mechanical logs and with

conventional core analysis data, thus facilitating the identification and correlation of specific facies throughout the field.

The log stratigraphic cross-sections, and various facies maps were constructed using a combination of mechanical logs, core lithologs, and porosity-permeability core analyses. All types of mechanical logs were utilized for determining the position of important marker beds, and facies unit thicknesses.

Log stratigraphic cross-sections, designated A-A' to G'-G", are included as enclosures to this report, with the cross-section localities indicated on Figure 6. Detailed gamma-ray cross-section mosaics of the north and south parts of the field, are also included in the enclosures, with the mosaic section localities depicted in Figure 14. All of the maps occur in page-size format within the text, and in undraughted large scale format as separate enclosures.

FACIES ANALYSIS

The Viking Formation in the Crystal area can be grouped into three major facies based upon interpretation of lithofacies sequences in cores: 1) Regional facies, 2) Channel facies and, 3) Estuary bay-fill facies. The term "regional facies" refers to the lithofacies sequence that characterizes the Viking Formation in the areas surrounding the Crystal field. Numerous studies indicate that the Viking Formation exhibits a relatively uniform facies sequence throughout many parts of south-central and central Alberta (Reinson et al, 1983; Reinson, 1984; Reinson and Foscolos, in press; Beaumont, 1984), including the region adjacent to the Crystal field. It is necessary to delineate what constitutes this 'normal' regional sequence in order to interpret the 'abnormal' Viking sequences that occur within the Crystal field.

Regional facies

The core illustrated in Figure 7, situated on the eastern margin of the Crystal field, is characteristic of the lithological sequence encountered in the Viking Formation throughout central and south-central Alberta. For the most part, the

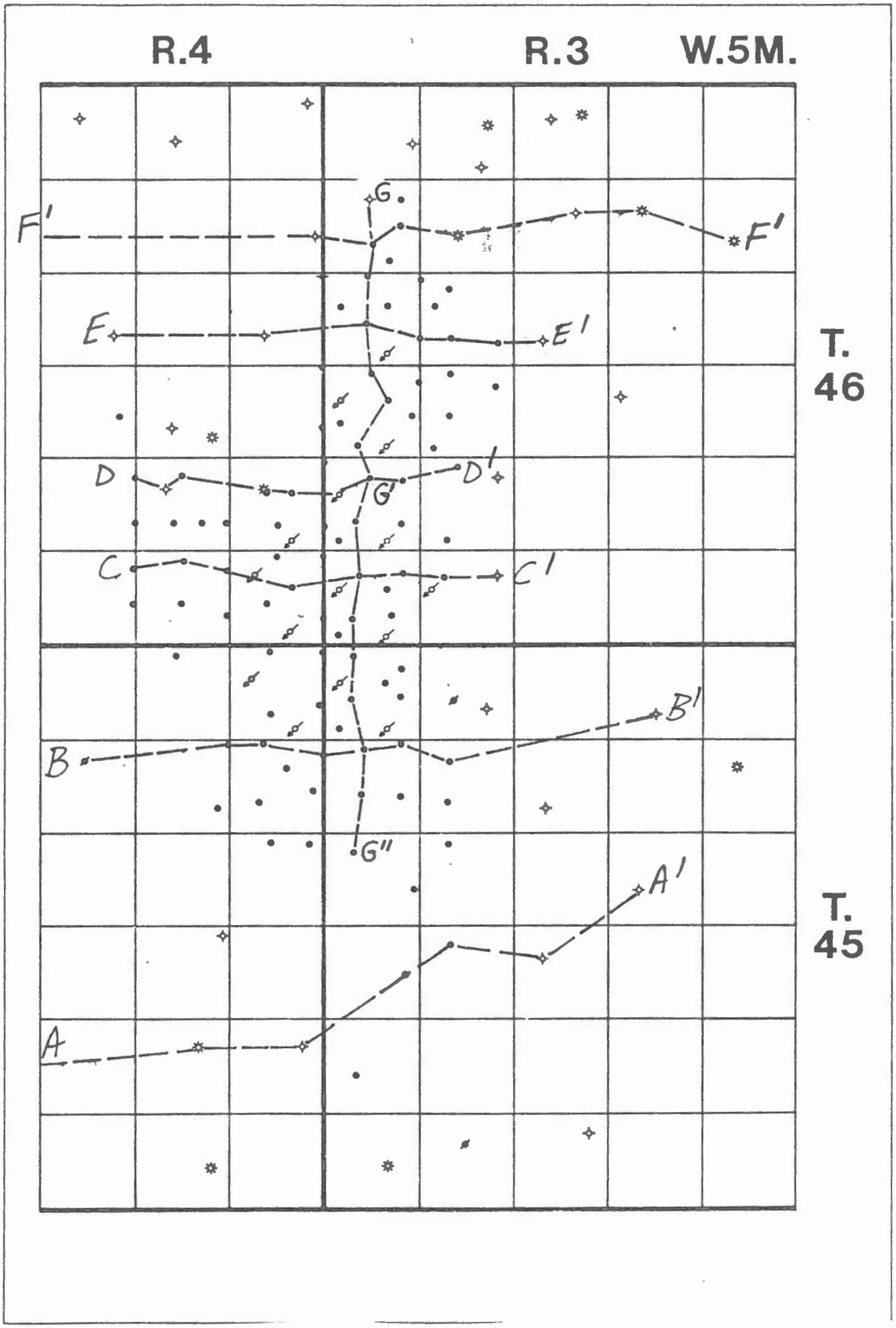

Figure 6. Map showing locations of the large-scale stratigraphic cross-sections (A-A' to G'-G") which form part of the enclosure supplement to this report.

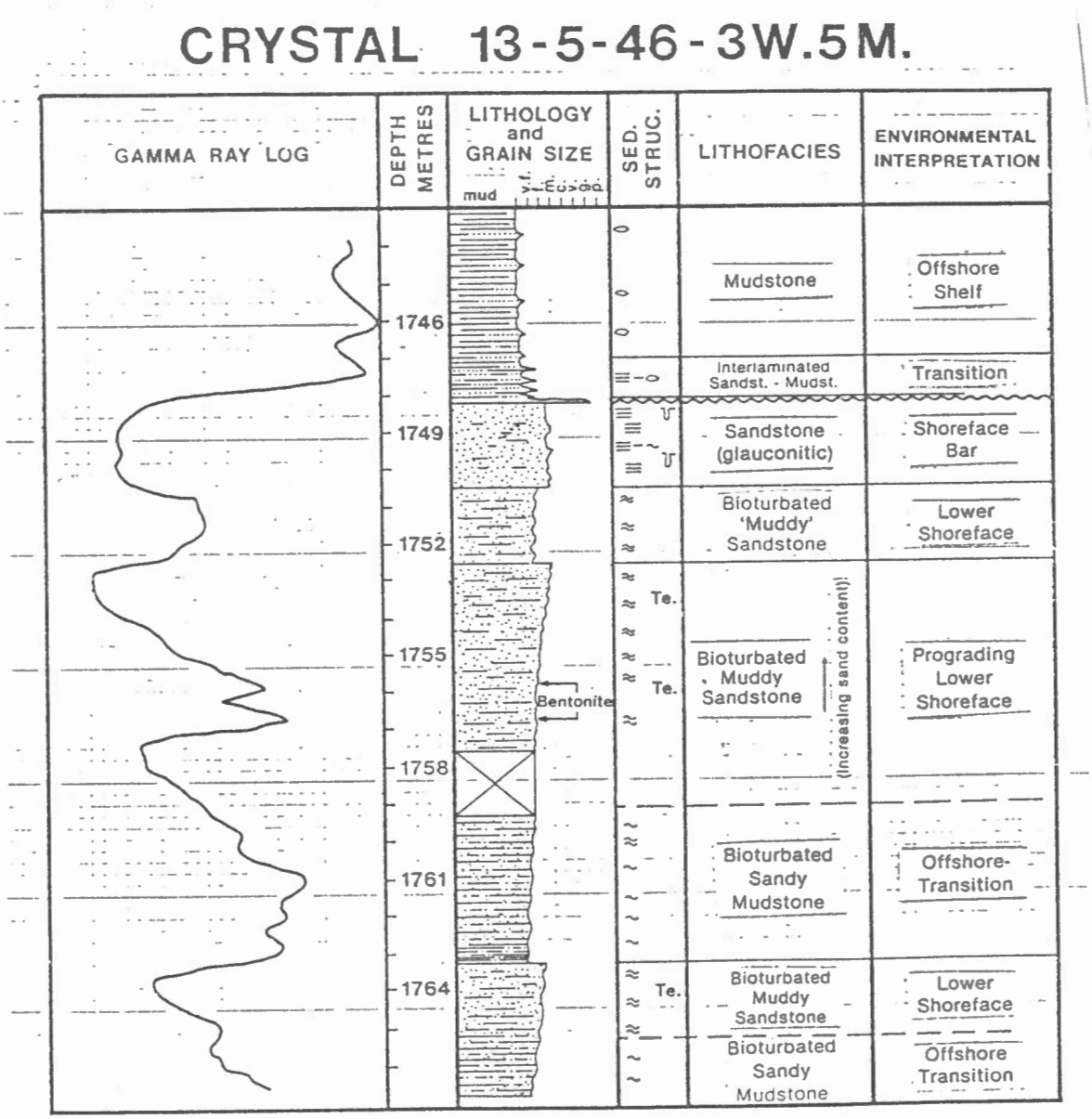

Figure 7. Interpretive litholog of the cored sequence in the 13-5-46-3W5 well. This cored sequence is typical of the 'regional facies' sequence.

regional Viking deposits consist of a series of coarsening-upward, bioturbated sandy mudstone to bioturbated muddy sandstone sequences. The bioturbated sandy mudstones are interpreted to represent offshore-transitional deposits, while the bioturbated muddy sandstones represent lower shoreface deposits resulting from progradation of the shoreface sediment wedge. Almost the entire formation is made up of four or five of these cyclic sequences, with the uppermost sequence often being capped by a 'clean', fine-grained shoreface bar sandstone lithofacies such as in the 13-5 well (Figure 7). The shoreface bar sandstone forms a marginal oil and/or gas reservoir at many isolated localities throughout the region. A fourth lithofacies, laminated to bioturbated sandstone-mudstone, though not present in all cored sequences, is a variant of the bioturbated muddy sandstone lithofacies (i.e: 8-7-46-3W5, Appendix I). Where present, it overlies and interbeds with bioturbated muddy sandstones, and represents the gradational interval between the bioturbated muddy sandstones and succeeding 'clean' bar sandstone deposits.

The cyclic coarsening-upward sequences of the regional Viking deposits impart a distinct log signature with the top of each cycle being expressed by a pronounced 'kick' on the gamma-ray log (Fig. 7). These kicks provide extremely useful markers for log-correlation purposes (i.e. see log cross-sections, marker B). Present within the regional Viking sequence are two bentonite layers, less than 1 cm thick, which give a characteristic 'double kick' on the gamma-ray log (Fig. 7). This kick was also used as a correlative marker and is designated 'bentonite marker' on the correlative cross-sections. A third correlative log marker, termed 'marker A' on the cross-sections, corresponds to another thin bentonite layer situated near the base of the formation.

Estuarine channel facies

Based on detailed examination of cores throughout the field, the Crystal sand body is interpreted as a multistage estuarine channel-fill deposit. The deposit consists of several channel-associated lithofacies including conglomerate, conglomeratic

sandstone, interbedded sandstone-conglomerate, fine- to medium-grained sandstone, fine-grained shaly sandstone, and partially bioturbated shaly sandstone (figs. 8-11). The variation in sand lithologies reflects different channel subfacies corresponding to the various subenvironments within the overall channel complex. Fine-grained shaly sandstones and partially bioturbated shaly sandstones are indicative of subtidal bar and bar-margin deposition along the laterally accreting or convex side of the channel complex. The principal reservoir-grade lithofacies, conglomerate, conglomeratic sandstone, and fine- to medium-grained sandstone, reflect deposition proximal to the axis, or on the scouring or concave margin, of the channel complex. The thick conglomerate lithofacies sequences are restricted to two localized areas (Fig. 12), with the bulk of the reservoir body being comprised of channel sandstone subfacies.

The channel origin of the sand body, as interpreted from cores, is corroborated by well-log correlations as illustrated in Figure 13. The distinctive marker horizons of the regional Viking facies sequence situated on the eastern margin of the field, are successively truncated as the sand body thickens to the west.

The correlation in Figure 13 would suggest a simple channel situation with progressively deeper channel incisement into older regional facies as the channel axis is approached. The variation in vertical facies successions from one core locality to another however, clearly indicates that the Crystal deposit is far more complex than that which could result from downcutting and in-fill by a single channel phase. This complexity is emphasized by the well cores illustrated in figures 8 and 9 which are located less than 0.5 km apart, yet contain completely contrasting vertical lithofacies successions.

At least three major superimposed channel-fill stages are recognizable in several cored sequences situated in the centre of the field (figs. 8, 9), whereas on the east and northeast sides only a single channel-fill event is evident (Fig. 10). In the southern part of the field, thick sandstone successions lacking conglomerate intervals, display

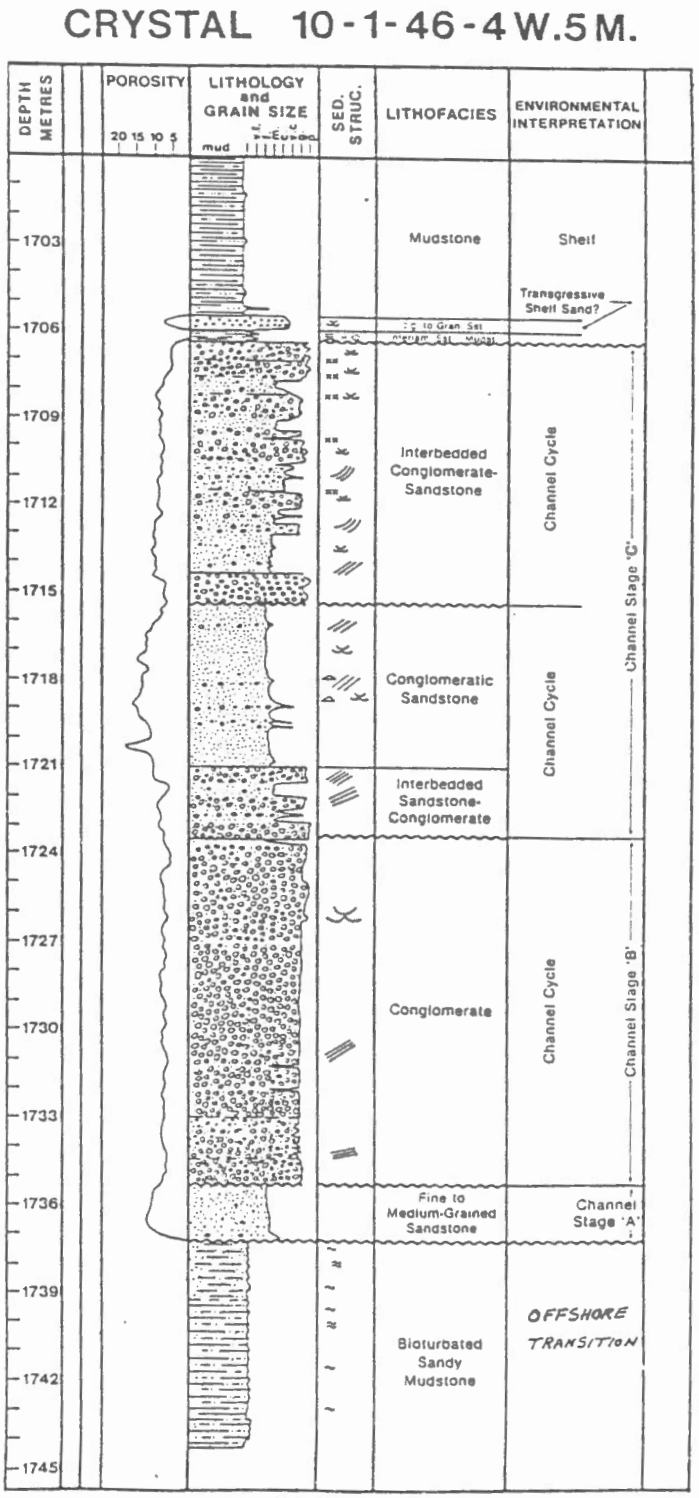

Figure 8. *Interpretive litholog of the cored sequence in the 10-1-46-4W5 well. (This core is located less than 0.5 km from the core illustrated in Figure 9).*

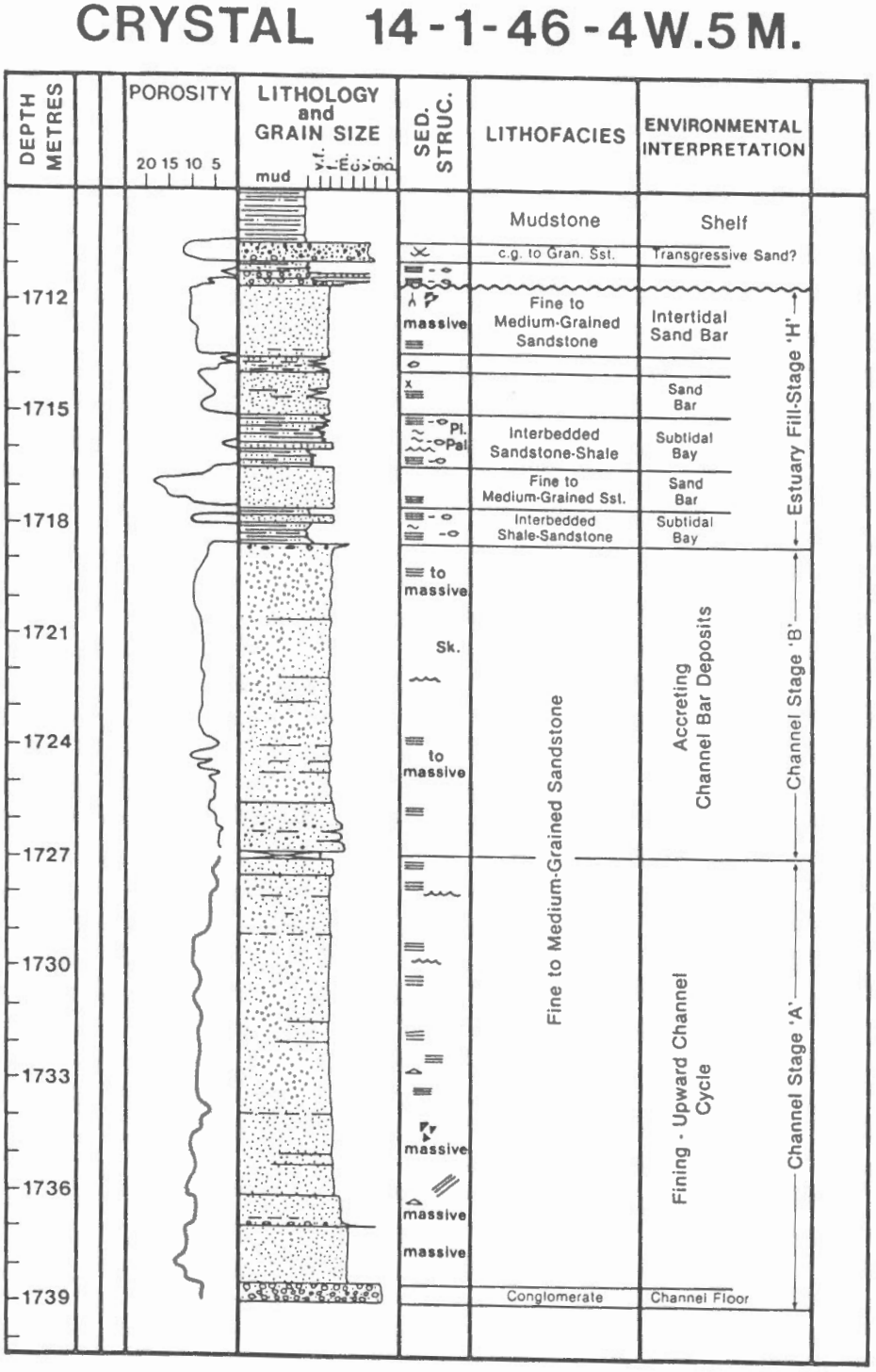

Figure 9. *Interpretive litholog of the cored sequence in the 14-1-46-4W5 well.*

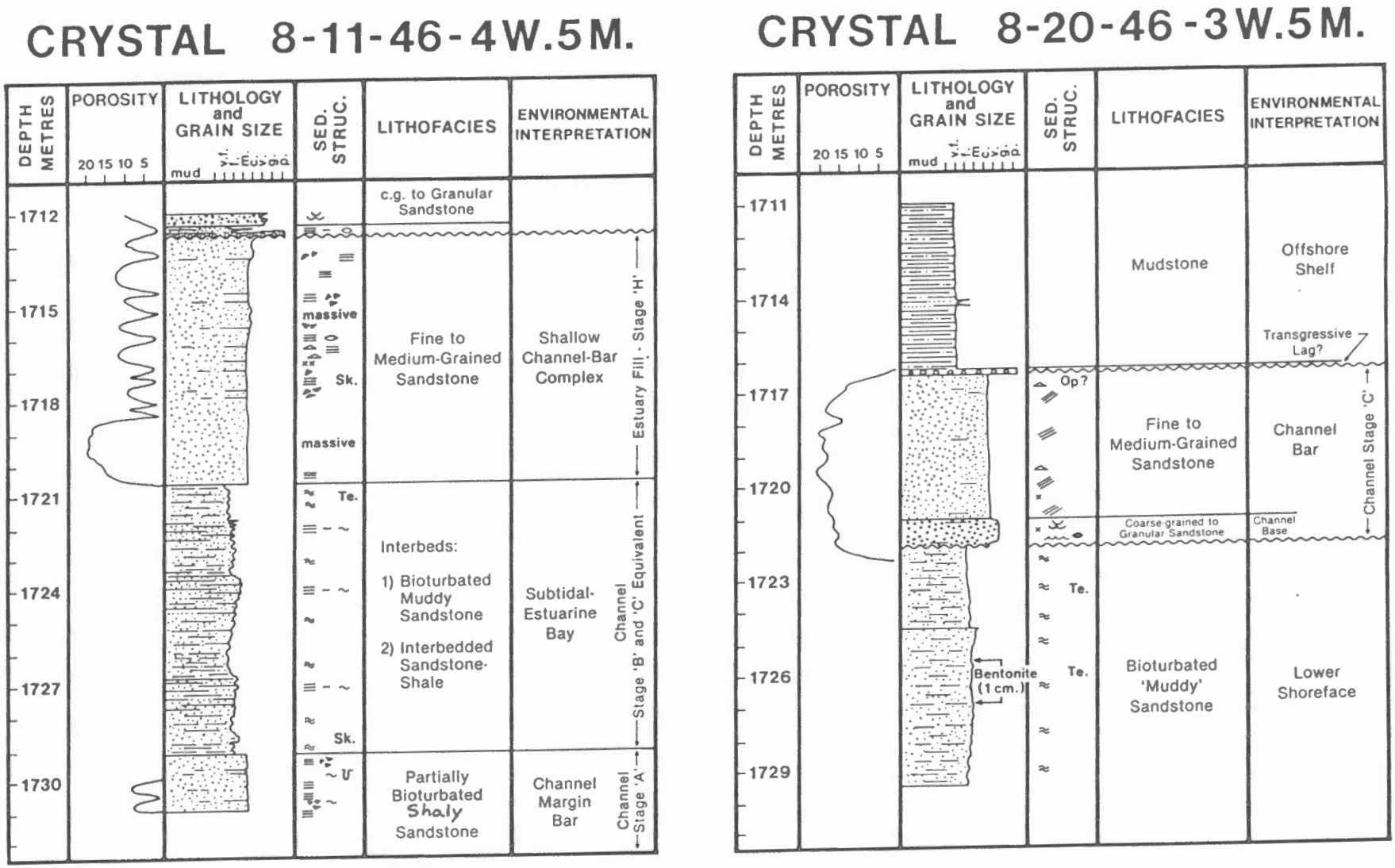

Figure 10. Interpretive lithologs of cores from the 8-11-46-4W5 and 8-20-46-3W5 wells. Note the contrasting facies sequences exhibited by the two well cores.

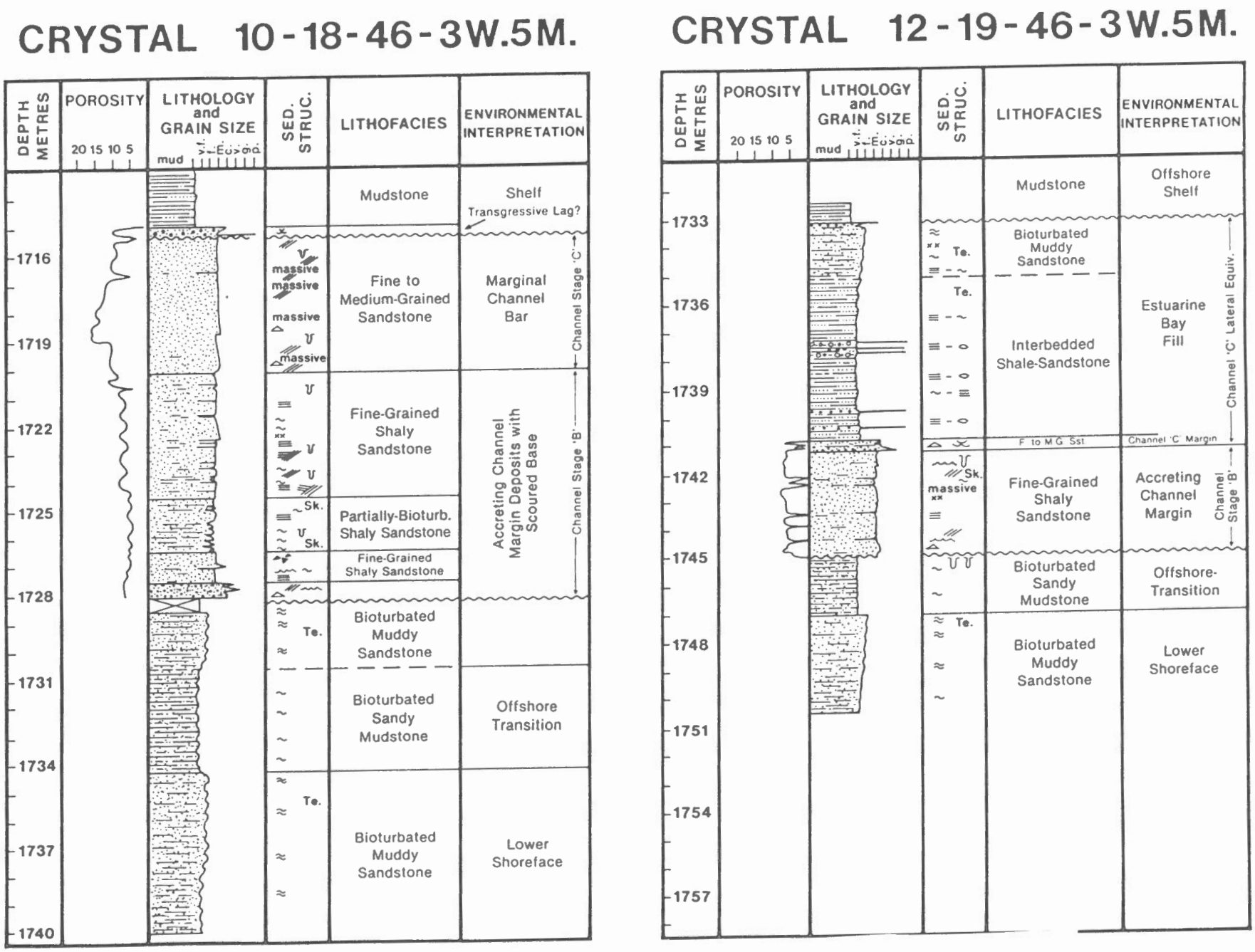

Figure 11. Interpretive lithologs of cores from the 10-18-46-3W5 and 12-19-46-3W5 wells. The facies sequences differ substantially, yet these wells are less than 1.5 km apart.

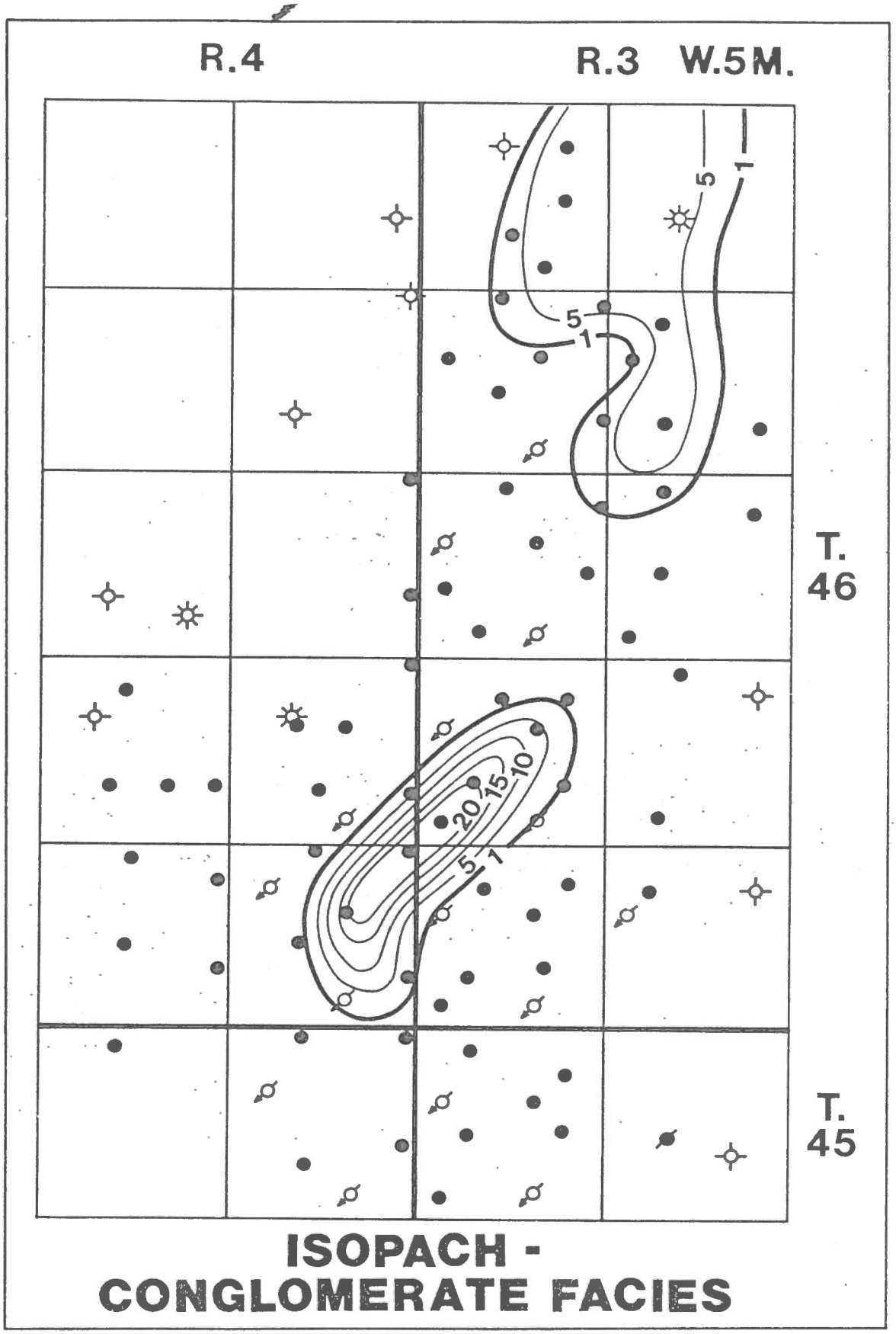

Figure 12. Isopach map of conglomerate facies. (Isopach line interval is 5 m, with the 1 m line also shown).

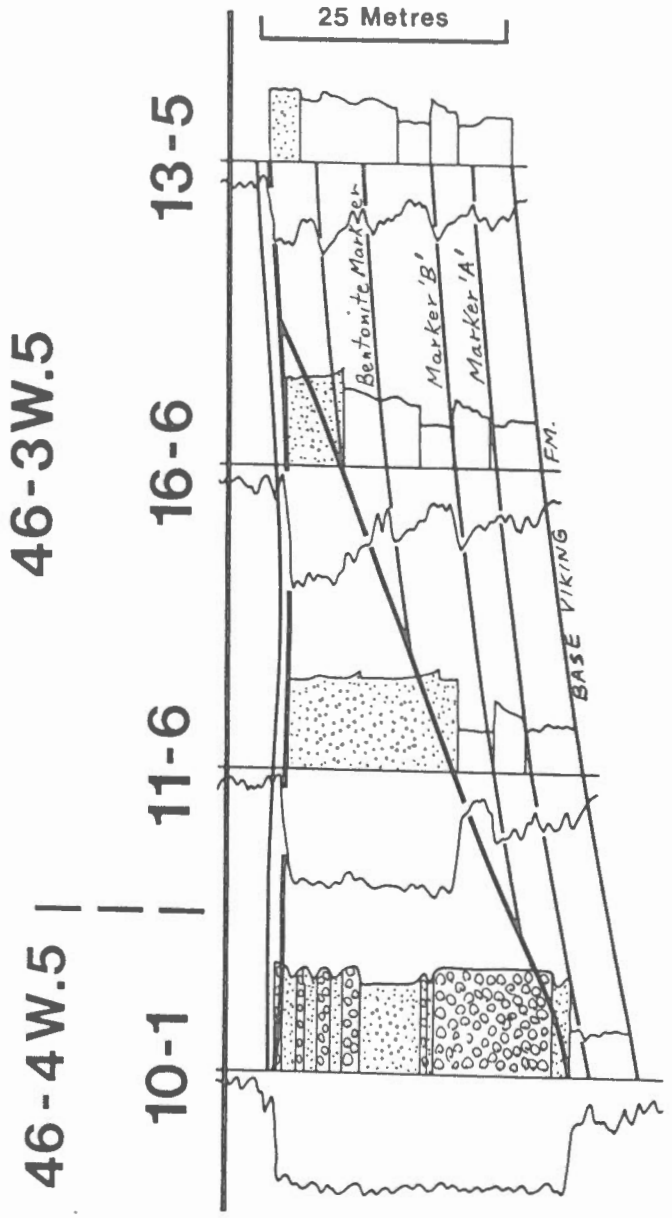

Figure 13. GR log-lithology cross-section from the eastern margin to the centre of the field, showing the unconformable relationship between the Crystal deposit and regional Viking facies. (Datum: Base of fish scales minus 30 m).

marginal-marine, subtidal channel affinities, but differentiation into discrete channel stages is difficult on the basis of core examination alone. Further variations in vertical facies succession occur on the western flanks of the sand body where the channel facies is characterized by sharply-based, fining-upward, progressively more shaly channel sandstone sequences, or by discrete shaly sandstones of the subtidal accreting channel margin interbedded with thick 'muddy' sequences of the estuary bay-fill facies, discussed in the next section.

Estuary bay-fill facies

This facies can be categorized into two broad groups, a lower estuarine 'muddy' subfacies and an upper shallow channel-bar sandstone subfacies. Subtidal estuarine 'muddy' deposits do not form any part of the reservoir body, whereas sandstones of the shallow channel-bar complex constitute the producing reservoir of the 'H' pool.

The muddy subfacies is characterized by thick units consisting of alternating, laminated to thin-bedded shale and sandstone (figs. 10, 11), which are often interbedded with bioturbated muddy sandstones similar to those occurring in the regional facies (Fig. 7). The estuarine 'muddy' subfacies, however, differs from the muddy sequences of the regional facies in both bedding aspect and trace-fossil assemblages. The difference between the two muddy facies is also clearly evident on gamma-ray well-log signatures (see cross-sections C-C', D-D', E-E', F-F'). Log signatures of the estuarine 'muddy' subfacies display an irregular, disordered deflection to the right, whereas the log signature of the regional facies displays a more ordered curve consisting of stacked funnel-shaped segments (Fig. 7).

The shallow channel-bar complex subfacies consists primarily of carbonaceous fine- to medium-grained sandstone, with root structures evident near the top of the subfacies in some cored sequences. This subfacies is sharply-based, displaying channel aspects at some localities, but in other areas only bar sandstones are present, often occurring in interbedding association with the estuarine muddy subfacies (Fig. 9).

The estuary bay-fill facies is present only on the western side of the Crystal field. Cored sequences in this region indicate that vertical successions of this facies vary substantially as follows. In the northern part of the field the estuary-bay facies consists only of the estuarine 'muddy' subfacies (Fig. 11). Towards the south sandstones of the shallow channel-bar subfacies are present, and separated from underlying channel facies by estuarine muddy subfacies (Fig. 10). Eastward toward the centre of the field estuarine 'muddy' subfacies thin and interbed with the shallow channel-bar subfacies (Fig. 9) which in turn becomes superimposed on top of reservoir channel facies. In the south part of the field sandstones of the shallow channel-bar complex amalgamate with sandstones of the channel facies and are virtually indistinguishable from the underlying channel sandstones on the basis of core examination alone.

Upper contact zone facies

Cored sequences through the upper contact of the Viking Formation indicate that all three major facies successions are overlain by a thin zone containing a similar sequence of facies (figs. 7-11). A very thin conglomeratic or granular layer invariably marks the top of each major facies, and this is interpreted to be a ravinement deposit formed during transgression by the lower Colorado sea. In the Crystal area, the thin conglomeratic lag is overlain either directly by lower Colorado shales, or by thin beds of two succeeding lithofacies, interlaminated sandstone-mudstone and coarse-grained to granular sandstone. The former lithofacies is thought to record deposition during the transition from shallow-marine to muddy shelf environments. The coarse-grained to granular sandstone lithofacies, which is trough crossbedded, is interpreted as a tidally-generated transgressive shelf-sand deposit.

Discussion

Lithofacies interpretations of cored sequences indicates that the Crystal Viking succession is characteristic of a marginal-marine depositional setting with the

combined association of facies representing some type of multistage estuarine tidal channel-bay complex. However, the stratigraphic relationships between the major facies, and the delineation of the equivalent channel stages within the channel complex, are not clearly evident from core examination alone. This is because of the superimposition of multiple channel-fill deposits, the lateral variation in lithofacies reflecting the various subenvironments within each channel deposit, and the interbedded association of successive channel-margin deposits with estuarine bay-fill facies to the west. The three-dimensional relationships of the facies and the delineation of equivalent channel events must be resolved through detailed correlative stratigraphy using well-log signatures supplemented by core lithofacies interpretations.

FACIES GEOMETRY AND DEPOSITIONAL RELATIONSHIPS

Stratigraphic relationships-regional Viking versus Crystal Viking

The log correlative section shown in Figure 13, and discussed previously, indicates that the eastern side of the Crystal Viking deposit is unconformable with underlying regional Viking deposits. The unconformable relationship of the Crystal Viking Channel facies with older regional facies is clearly evident in most cored sequences and mechanical log cross-sections. The east-west log stratigraphic cross-sections (B-B' to F-F') illustrate that this unconformity is not just local and due simply to channelization but more regional in nature, as elaborated upon below.

The lack of marker beds (particularly the bentonite marker) in the estuarine muddy subfacies, and the difference in gamma-ray log signature of this facies compared to the regional Viking facies, suggest that the estuary bay-fill facies is also unconformable with regional facies of the Viking Formation. Log correlations confirm this, with the bentonite marker, and markers A and B appearing in well-logs situated west of the Crystal field. The unconformity separates estuarine 'muddy' facies from regional 'muddy' facies on the western side, and channel facies from regional 'muddy'

facies on the eastern side (cross-sections C-C' to F-F'). In the centre of the field, the unconformable surface extends through the entire Viking Formation into the underlying Joli Fou Formation (cross-section C-C').

To summarize, based on log correlations supplemented by core examination, it can be demonstrated that: 1) the Crystal Viking deposits are younger than the regional Viking sequences, 2) estuarine bay-fill facies are laterally equivalent to the channel facies, and, 3) the estuary bay-fill and channel facies fill some pre-existing valley that was incised into older regional Viking deposits. Thus a major unconformity is present in the Viking Formation in the Crystal area.

Channel stages

A gamma-ray log mosaic of the entire field was constructed in order to delineate the major channel depositional events within the overall channel complex (Fig. 14). When the Crystal deposit is examined in this manner, the resolution and correlation of the channel facies into separate channel stages is possible (Fig. 15). The lateral relationship of each channel stage to the estuary bay-fill facies also becomes evident.

Four distinct units constitute the Crystal reservoir deposit. These are termed channel stage 'A', 'B' and 'C', and estuary-fill stage 'H'. Channel stages 'A', 'B' and 'C' correspond to three major estuarine channel-fill depositional events, and constitute the bulk of the reservoir, that is, the Crystal Viking 'A' pool. The sand body delineated as estuary-fill stage 'H', corresponds to the shallow channel-bar complex subfacies of the estuary bay-fill facies. It is given the term "stage 'H'" since it forms the reservoir for the Crystal Viking 'H' pool.

The deposits of the three channel stages exhibit a divergent pattern in the north, but throughout most of the field the channel-stage deposits are partially superimposed with a downcutting and scouring relationship clearly visible (Fig. 15, and GR cross-section mosaics). Southward, deposits of the three channel stages appear to amalgamate as one sand body, and separate channel stages are barely distinguishable either on logs or in core.

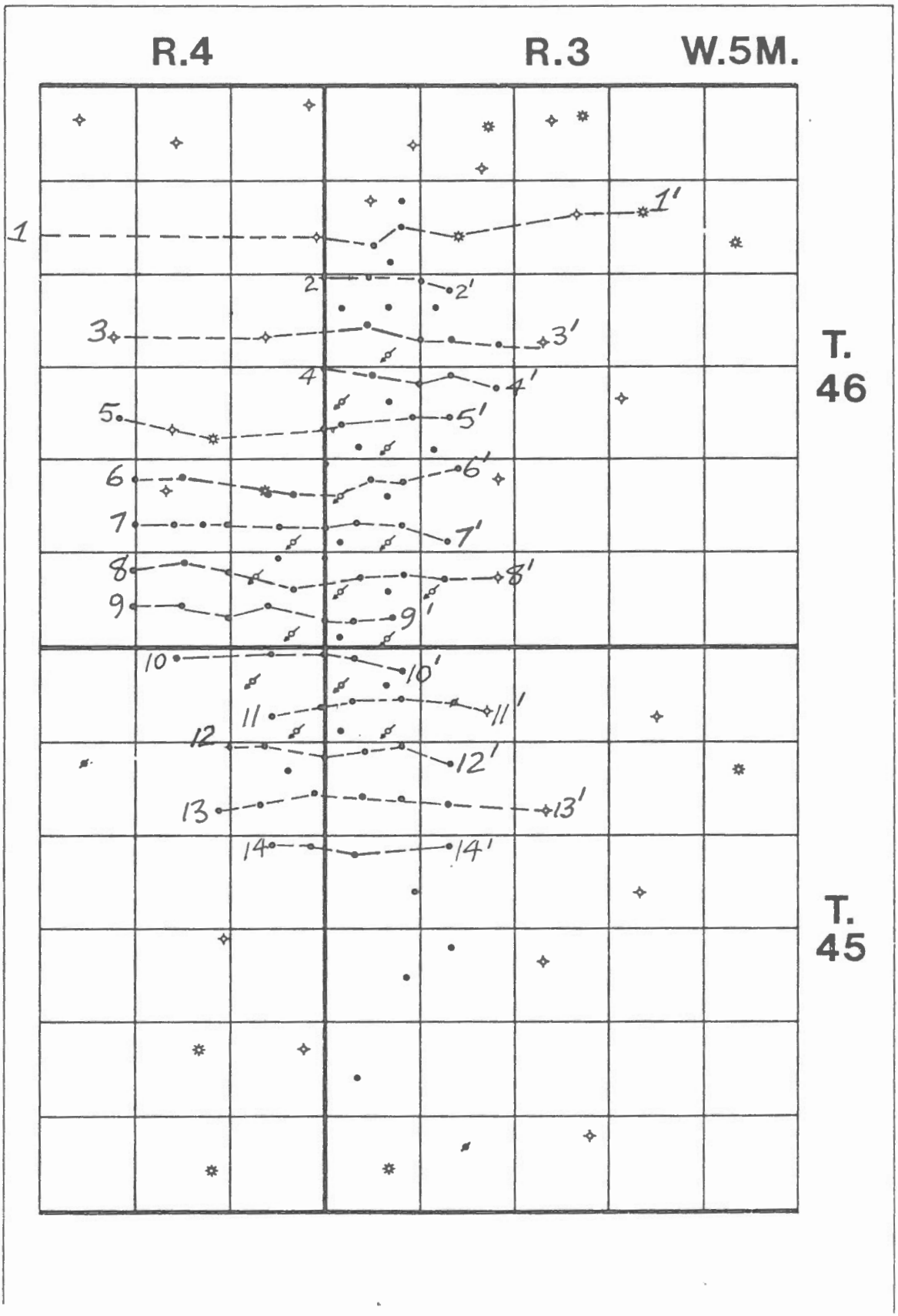

Figure 14. *Location of GR log sections illustrated in the cross-section mosaics of North and South Crystal. (Cross-section mosaics are included as enclosures).*

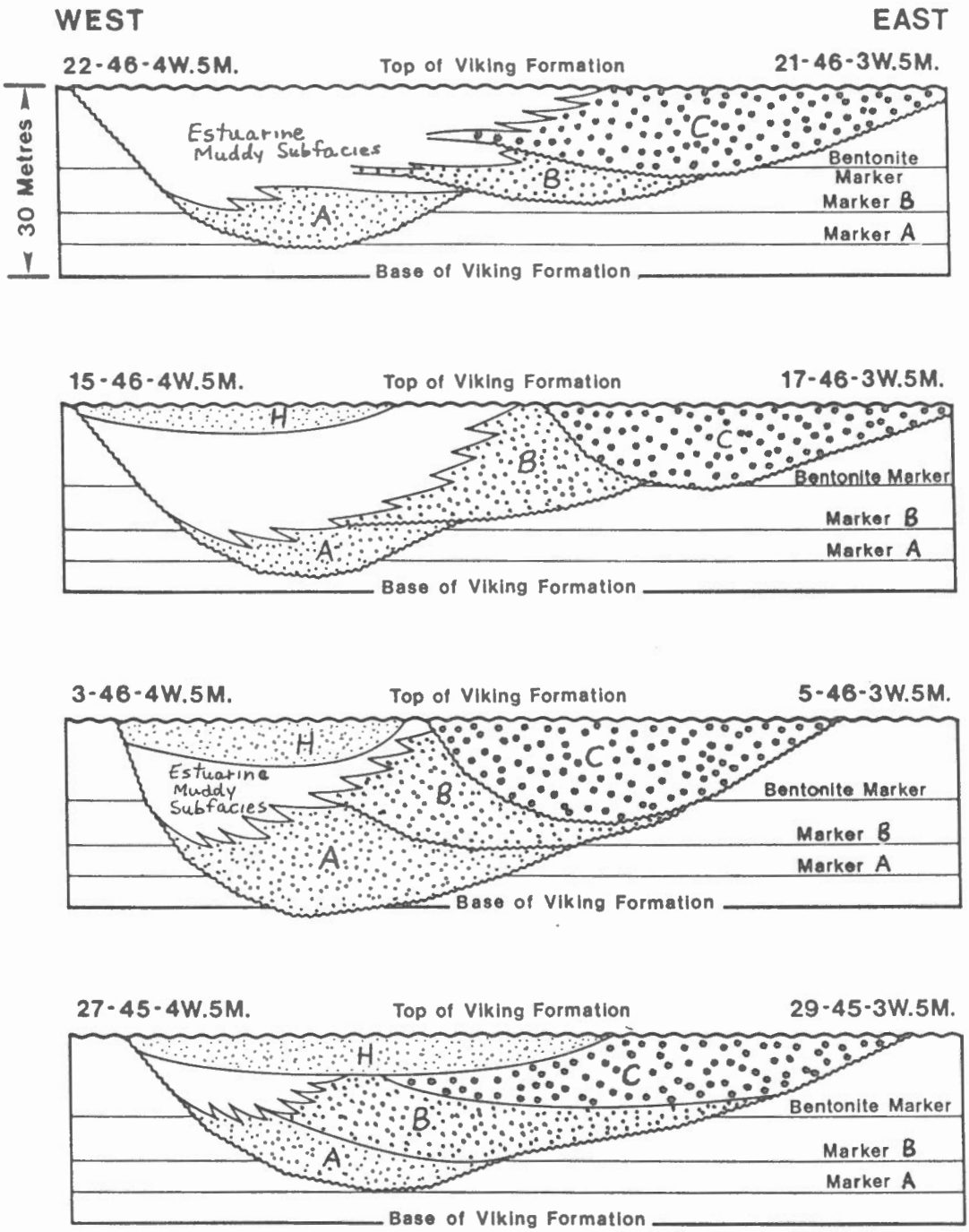

Figure 15. *Schematic diagram interpreted from the GR cross-section mosaics, illustrating the varying relationship of the three channel depositional stages and the estuary bay-fill stage, between the north and south parts of the field.*

An interbedding and gradational relationship is apparent on the western side of each channel deposit. This side would correspond to the laterally accreting margin of each channel stage, with the estuary bay-fill facies being the lateral facies equivalents of the channel sandstone-conglomerate deposits. The eastern side of each channel stage exhibits a sharp, truncated contact with adjacent facies, which may indicate that the concave or cutbank side of each channel stage was situated predominantly on the eastern side.

The regional distribution of the stage 'H' sand body (or shallow channel-bar complex) relative to the multistage estuarine channel deposits is clearly delineated in Figure 15. The stage 'H' sand is completely absent in the northern part of the field, but is present and thickens in a southward direction. As the stage 'H' sand thickens, it displays some channel characteristics, until it merges with estuarine channel deposits in the south part of the field, where it is difficult to differentiate from the underlying sandstone deposits.

DEPOSITIONAL MODEL

The Crystal Viking reservoir body is interpreted as a multistage tidal channel-fill complex deposited in a marginal-marine (estuarine) setting. The Crystal estuarine deposits are unconformable with underlying regional deposits of the Viking Formation, and the depositional model invoked here accounts for this unconformable relationship.

The Crystal Viking deposits are interpreted to have formed under the following sequence of events.

1. At the end of Joli Fou deposition a regressive stage began which corresponded to the initiation of Viking deposition. In the Crystal area this resulted in the deposition of a cyclic sequence of prograding shelf to shoreface sediment wedges, which have been referred to here as the "regional Viking facies".

2. Terminating this fluctuating but overall regressive event, was a major regional drop in sea level. This drop in sea level led to erosion and incisement of a

shallow but submarine linear valley into lower shoreface-inner shelf deposits of the regional Viking facies (Figs. 15, 16).

3. The resulting estuarine valley was then filled during a subsequent rise in sea level, with each of the channel depositional stages representing stillstands during an overall, and otherwise, continuously transgressive event. Each channel stage modified the estuary via erosion on the eastern margin, whereas the channel sand and conglomerate deposits intertongued laterally with estuary bay-fill sediments on the western side (figs. 15, 16).

4. The final estuary-fill eposide is represented by the shallow channel-bar complex of estuary fill 'stage H'. It is possible this complex may be representative of secondary channel or tidal-deltaic deposits which are genetically related to uppermost channel stage 'C' deposition.

5. After the estuary filled, deposition may have continued across the area. This is difficult to ascertain because of an ensuing rapid transgression of the lower Colorado sea which eroded the uppermost strata, leaving a thin, conglomeratic lag deposit across the entire area.

The depositional model proposed here is similar to the model postulated by Weimer (1983, 1985) for the equivalent Muddy J sandstone in the Denver Basin. In the Weimer model, however, the depositional setting for the Muddy J is interpreted as alluvial plain, as opposed to the marginal-marine setting for the Crystal Viking deposits as postulated here.

DEPOSITIONAL CONTROLS ON RESERVOIR CHARACTERISTICS

The Crystal reservoir sand body has been shown to consist of four major sandstone-conglomerate units, designated as channel stages 'A', 'B' and 'C' and estuary-fill stage 'H'. The three-dimensional distributions of each of the units relative to one another appears to bear directly upon the reservoir continuity and performance trends

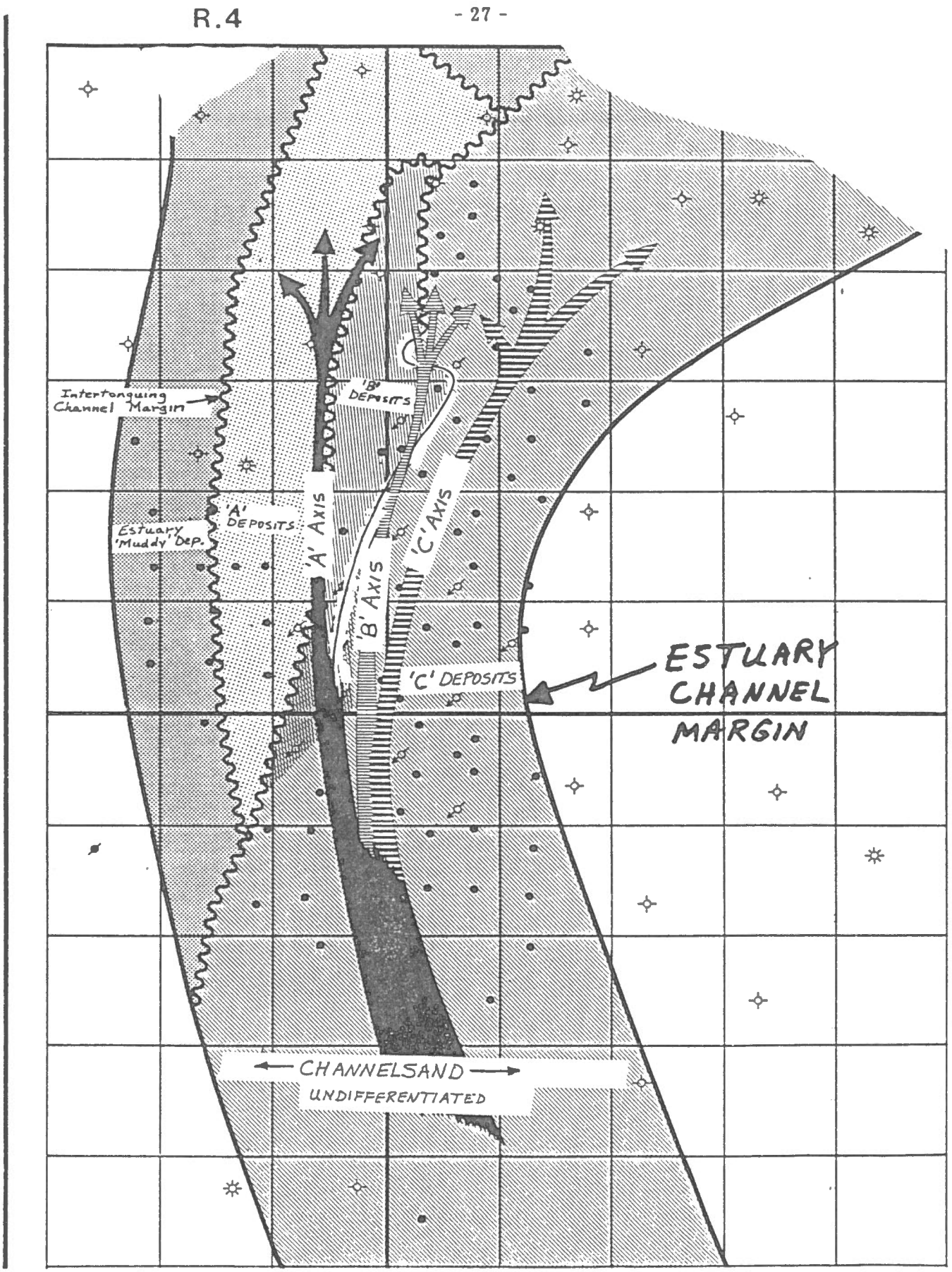

Figure 16. Schematic of the depositional model proposed for the Viking deposits in the Crystal area.

exhibited by the producing field. That is, the in-field variability in net-pay thicknesses, and performance trends of specific producing wells or groups of wells, and the occurrence of two hydrodynamically separated oil pools, is a function of the degree of amalgamation, superimposition and divergence of the four reservoir depositional units. When the deposits of specific channel stages are mapped separately, the relationships between the facies geometry and reservoir characteristics is readily apparent. Some of these relationships are elaborated upon below.

1. The most obvious example of depositional control on reservoir characteristics in the Crystal field, is the Crystal Viking 'H' pool. When mapped as a separate entity from the total reservoir sand body, the distribution of the shallow channel-bar complex subfacies (stage 'H' sand) corresponds to the distribution of the 'H' pool (figs. 5, 17). The line of separation of the stage 'H' sand from channel-stage deposits virtually marks the lower limit of water-free oil production in the 'H' pool. The divergence of stage 'H' sands from the main reservoir body by impermeable estuary muddy subfacies in a northward, or regionally updip direction, created favourable conditions for the occurrence of a secondary oil-pool that is isolated from the main oil-bearing reservoir.

2. The gross reservoir isopach (Fig. 3) indicates the occurrence of two linear thickening trends toward the north part of the field. The thickening trend in Tp. 46, Rg. 4W5 is a reflection of both the stage 'H' reservoir sand, and the channel stage 'A' deposit which diverges toward the north away from the main channel complex (Fig. 15). Fine-grained shaly sandstone and partially bioturbated shaly sandstone lithofacies, both of poor-reservoir quality, comprise the channel stage 'A' deposits in this area. These lithofacies reflect the intertonguing and "shaling-out" of channel stage 'A' sands toward the west and northwest margin of the estuarine valley, as shown in the cross-section mosaics (see enclosures). Such sands should not be expected to form part of the 'A' pool reservoir, and it is evident that they do not by the

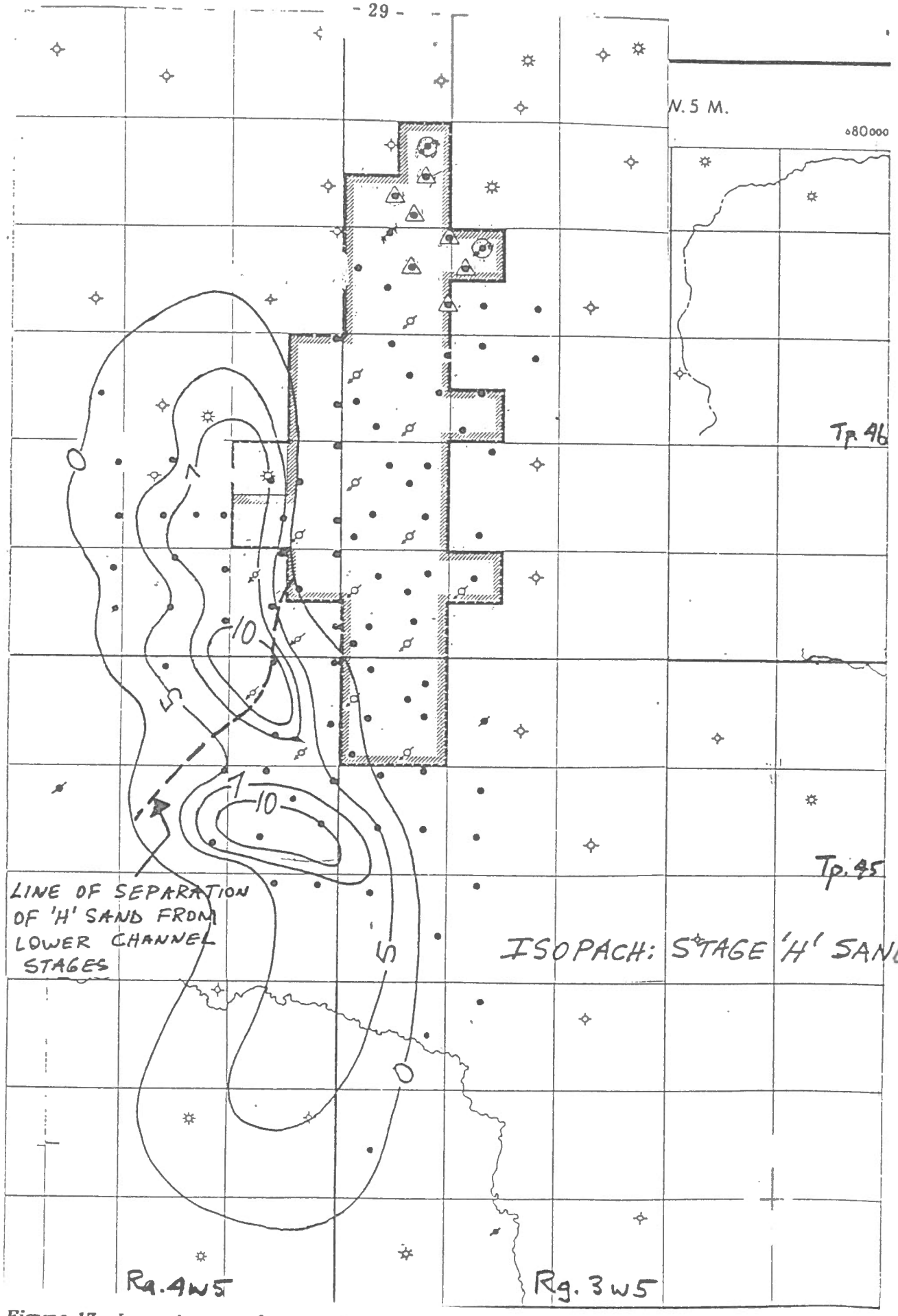

Figure 17. Isopach map of stage 'H' sandstone (shallow channel-bar complex subfacies of the estuary bay-fill facies). This sand deposit forms the reservoir of the 'H' pool. (The zero, 5, 7 and 10 m isopach lines are shown).

remarkable correspondence between the isopach of Channel 'B' and 'C' deposits and the limits of the 'A' pool (figs. 4, 18). Channel stage 'A' deposits, however, do contribute to the net-pay thickness of the 'A' pool in the central area of the field where they are extremely thick and partially superimposed by deposits of channel stages 'B' and 'C'.

3. The deposits of highest-reservoir quality appear to be those of channel stage 'C', both in core and on logs. When the channel stage 'C' deposit is isopached separately from the other units (Fig. 19), there is a definite correspondence between the distribution of the stage 'C' deposit, and the "sweet-zone" of the reservoir (Fig. 20). Thus, of the four distinct reservoir units, stage 'C' should be expected to have the highest productive capability.

4. Maximum reservoir continuity trends between producing wells of the 'A' pool should be aligned north-south, corresponding to the alignment of specific channel-stage deposits. Conversely, permeability barriers might be expected to occur between wells oriented in an east-west direction from each other. For example, in section 4-4' and 5-5' of the cross-section mosaic of North Crystal, the 16-13, 14-18, 8-13 and 5-18 wells penetrate shaly sandstone lithofacies or more shaly-upward (fining-upward) sequences situated at the accreting margins of channel stage 'B'. These wells penetrate poor-quality reservoir sands, in contrast to the 16-18 and 8-16 wells, which contain porous channel bar or axial channel facies of stage 'C'. Poor reservoir communication between the two sets of wells should be anticipated. Preliminary results from a water-injection well situated in the stage 'B' marginal channel deposits in section 18 confirm this. Wells situated in marginal channel facies of stage 'B' immediately flooded-out, while there was no response to the injection in the producing wells to the east which penetrate porous channel stage 'C' deposits.

It is obvious from the above examples that depositional controls on facies distributions and reservoir geometry govern, in large part, the reservoir continuity and performance trends of the Crystal Viking field. Thus, it is apparent that facies

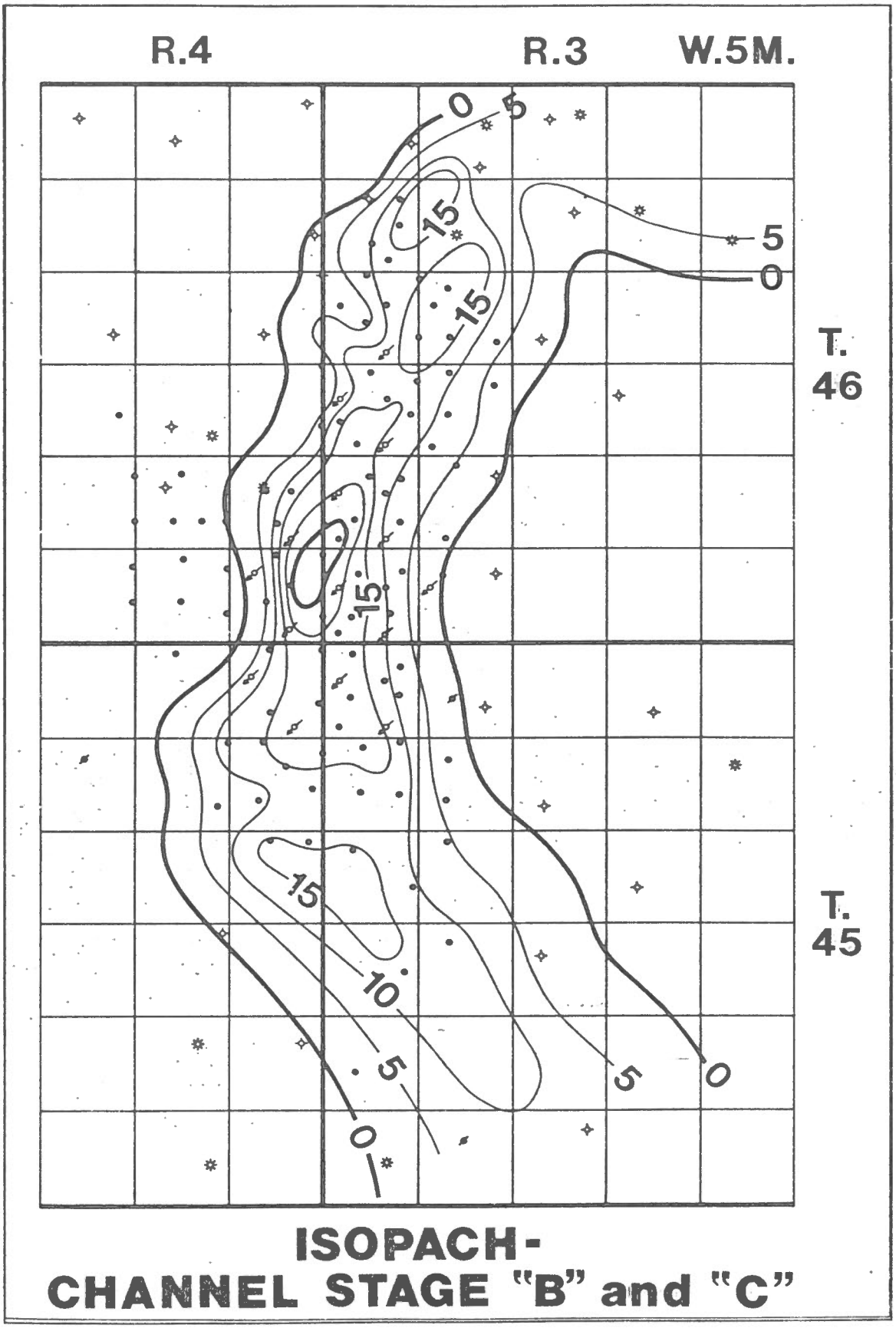

Figure 18. Isopach map of the total thickness of channel stage 'B' plus 'C' deposits (isopach line interval - 5 m).

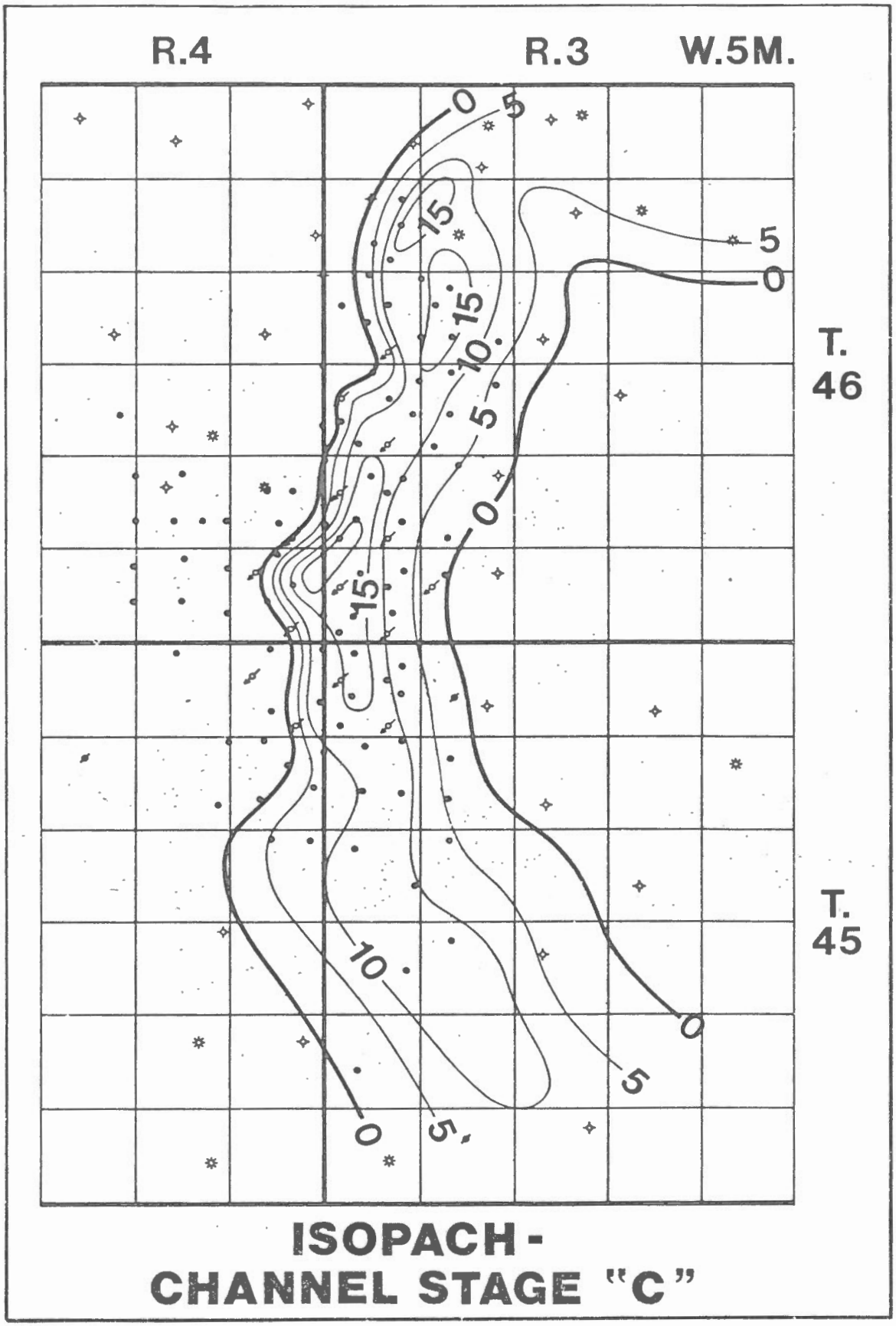

Figure 19. Isopach map of channel stage 'C' deposits (isopach line interval - 5 m).

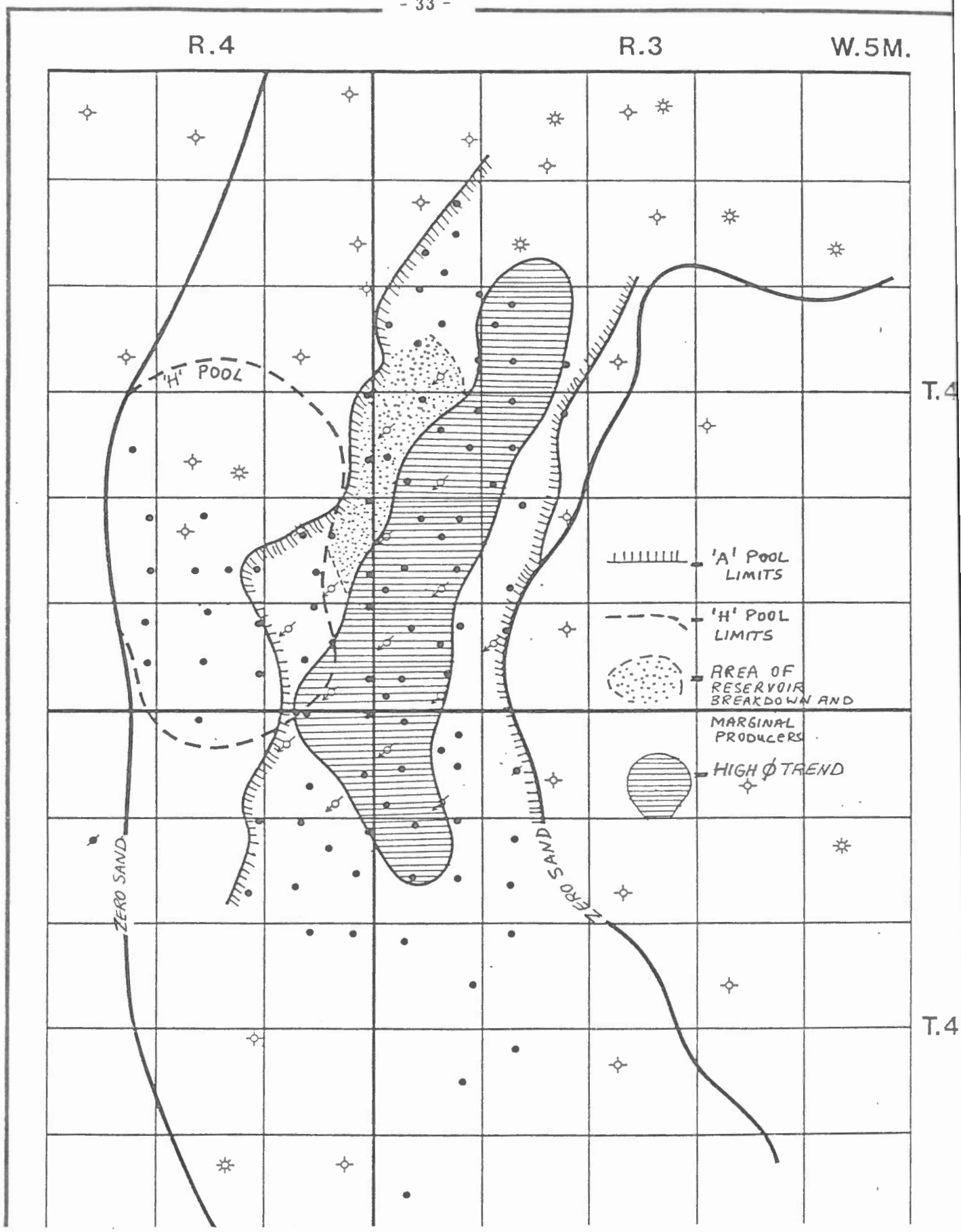

Figure 20. Schematic map highlighting the principal reservoir trends that are governed by depositional factors.

distributional trends and channel stage geometries should be taken into account during both the planning and evaluation phases of any secondary waterflood scheme.

SUMMARY AND CONCLUSIONS

1. The Viking Formation in the Crystal field is comprised of a linear, north-south trending, sandstone-conglomerate deposit ranging up to 30 m thick. This contrasts sharply with other producing Viking fields in south-central Alberta, which are generally elongated in northwest-southeast to north northwest-south southeast directions and have reservoir zones in the order of 2 to 10 m thick.

2. The Viking facies sequence situated at the margins of the Crystal field is typical of the regional Viking facies succession, which is characterized by a series of stacked, coarsening-upward sequences consisting of bioturbated sandy mudstone to bioturbated muddy sandstone. These stacked sequences are interpreted to represent cyclic progradation of the lower shoreface sediment wedge, with the sporadic occurrence of 'clean' sandstone at the top of the cyclic sequence being indicative of shoreface bar development.

3. Facies sequences within the Crystal field differ markedly from the regional Viking facies succession. Detailed core examination indicates that the Crystal deposits consist of two major facies, channel and estuary bay-fill, with the combined association of facies representing an estuarine tidal channel-bay complex. Multiple superimposed channel-fill deposits comprise the linear reservoir sand body, which is unconformable with underlying and adjacent regional Viking facies.

4. Log stratigraphic correlations clearly indicate that not only is the channel facies unconformable with underlying regional facies, but that estuary bay-fill facies and channel facies are lateral equivalents. Further, both facies fill some pre-existing valley that was incised into older regional Viking deposits. Thus a major unconformity occurs within the Viking Formation in the Crystal area.

5. Detailed 'in-field' correlations indicate that the reservoir sand body is comprised of four depositional units, corresponding to three successive and partially-superimposed channel-fill stages (A, B and C) and a final estuary-fill stage (H). Deposits of channel stages 'A', 'B' and 'C' constitute the bulk of the reservoir and form the Crystal Viking 'A' pool. The stage 'H' sand is the uppermost unit of the estuary bay-fill facies and forms the reservoir for the Crystal Viking 'H' pool.

6. The multistage channel depositional events are thought to be a record of progressive estuarine valley fill under conditions of rising sea level, with each channel depositional stage representing a stillstand during an overall transgressive event. Each channel stage modified the estuary on the eastern side while subtidal estuary bay-fill deposits accumulated, as facies equivalents to the channel-fill deposits, on the western side. The final estuary-fill episode is recorded in the form of shallow channel-intertidal bar deposits represented by the reservoir sandstones of the 'H' pool.

7. The occurrence of two separate pools ('A' and 'H' pools), and the variability in reservoir capacity, continuity and performance trends of the 'A' pool, can be shown to be directly controlled by depositional factors. The proposed depositional model readily accounts for the occurrence of the 'H' pool as a discrete reservoir separated from the main oil-bearing 'A' zone pool. The highly productive wells of the 'A' pool correspond to specific channel stage deposits, or are situated in the areas where channel deposits of successive stages are highly superimposed. In contrast, marginally productive wells and poor reservoir communication between producing wells, occur where the different channel-stage deposits are shown to diverge.

8. Since the facies distributional trends and channel stage geometries can be demonstrated to account for specific continuity and performance trends exhibited to date by the producing field, it is obvious that such depositional controls must be taken into account during both the planning and evaluation phases of any secondary recovery scheme.

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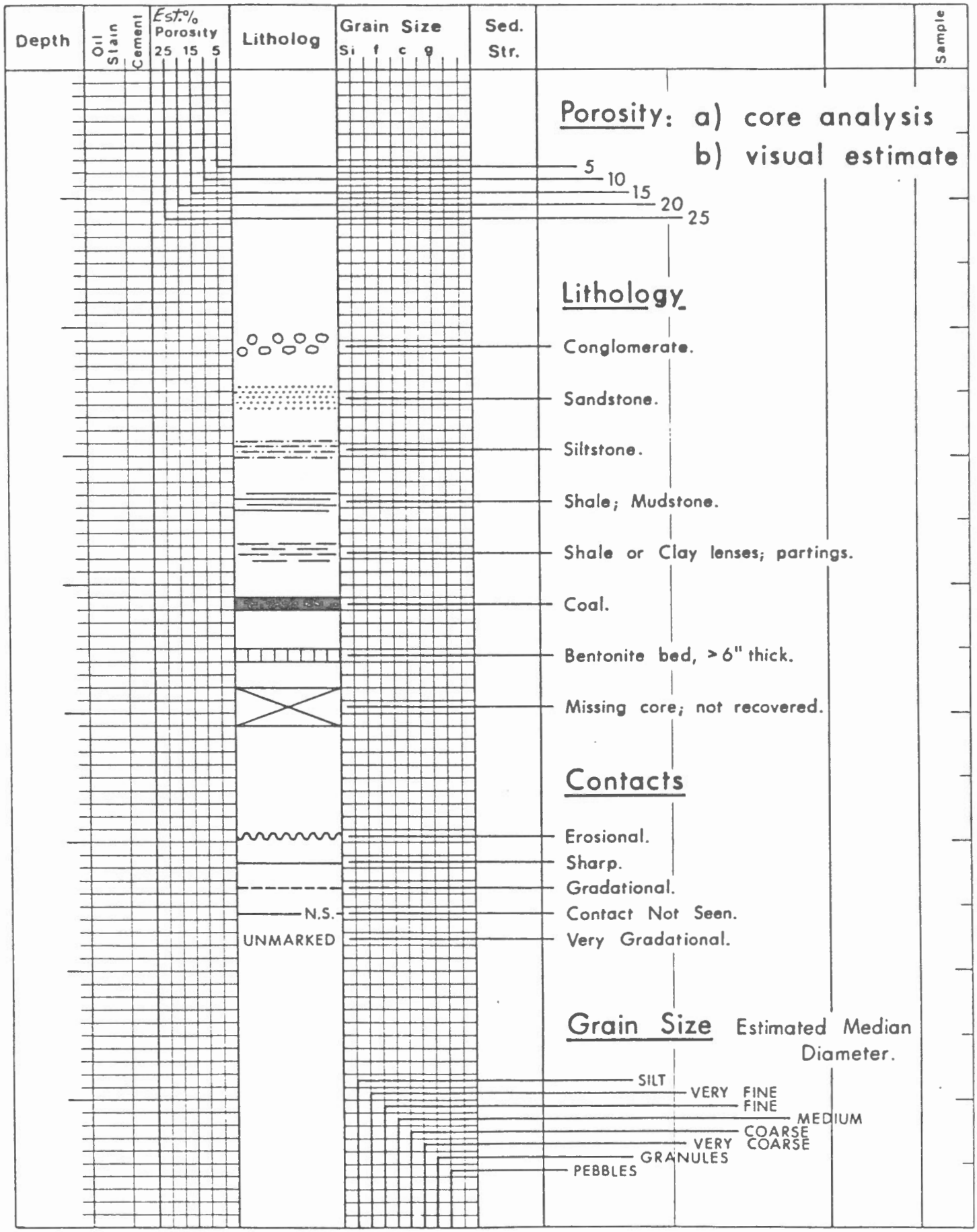
APPENDIX I

Core Lithologs

Well Name Legend for Lithologs.

Location _____ Core Interval _____



CORE LITHOLOG SYMBOLS

BEDDING STRUCTURES

No Symbol - MASSIVE; STRUCTURELESS

LAMINATIONS


HORIZONTAL PARALLEL

FAINT PARALLEL

DISCONTINUOUS, WISPY


INCLINED PARALLEL


WAVY PARALLEL

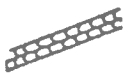

GENTLY CURVILINEAR

CROSS - STRATIFICATION


CURRENT RIPPLES


WAVE RIPPLES


UNDIFFERENTIATED, COMBINATION RIPPLES


RIPPLE - DRIFT


TROUGH CROSS-BEDS


PLANAR CROSS-BEDS

MISCELLANEOUS


GRADED BEDDING


INVERSE GRADED BEDDING


LENSES, LENTICULAR BEDDING


FLASER BEDDING


CONTORTED, CONVOLUTE BEDDING (LAMINATIONS)


DISRUPTED BEDDING; MICROFAULTS, FRACTURES, ETC.


SLUMP, FLOW STRUCTURES


SOLE MARKS; GROOVES, FLUTES, SCRATCHES, LOADCASTS.


RIP-UP CLASTS


MUD CRACKS


STYLOLITES


IMBRICATION

MISCELLANEOUS SYMBOLS

$B^{2"}$ BENTONITE LAYERS; THICKNESS

x x FERRUGINOUS; NODULES, BANDS, CONCRETIONS


PLANT, WOOD FRAGMENTS


CARBONACEOUS PARTINGS PARTICLES


ROOTLETS


COAL, LENSES, STREAKS, PARTINGS

~ BIOTURBATED

≈ EXTENSIVELY BIOTURBATED; CHURNED, MOTTLED


BURROW; VERTICAL, HORIZONTAL


SHELLS

Tr. IDENTIFIABLE TRACE FOSSIL

≡— ~ LAMINATED TO BIOTURBATED

LITHOLOGY

 — CONGLOMERATE

 — COARSE-GRAINED TO GRANULAR SANDSTONE

 — VERY FINE TO MEDIUM-GRAINED SANDSTONE

 — SILTSTONE

 — SHALE

XX — FERRUGINOUS NODULES, BANDS, CONCRETIONS

 — CLAY CLAST

TRACE FOSSILS

Te. — TEREBELLINA

Pl. — PLANOLITES

Sk. — SKOLITHOS

Pal. — PALEOPHYCUS

Op. — OPHIOMORPHA

Tc. — TEICHICHNUS

STRUCTURES

 — LOW-ANGLE CROSSBEDDING

 — TROUGH CROSSBEDDING

 — PARALLEL LAMINAE

 — WAVY, LENTICULAR LAMINAE

 — WAVE RIPPLES

 — CURRENT RIPPLES

 — SOLE MARKS

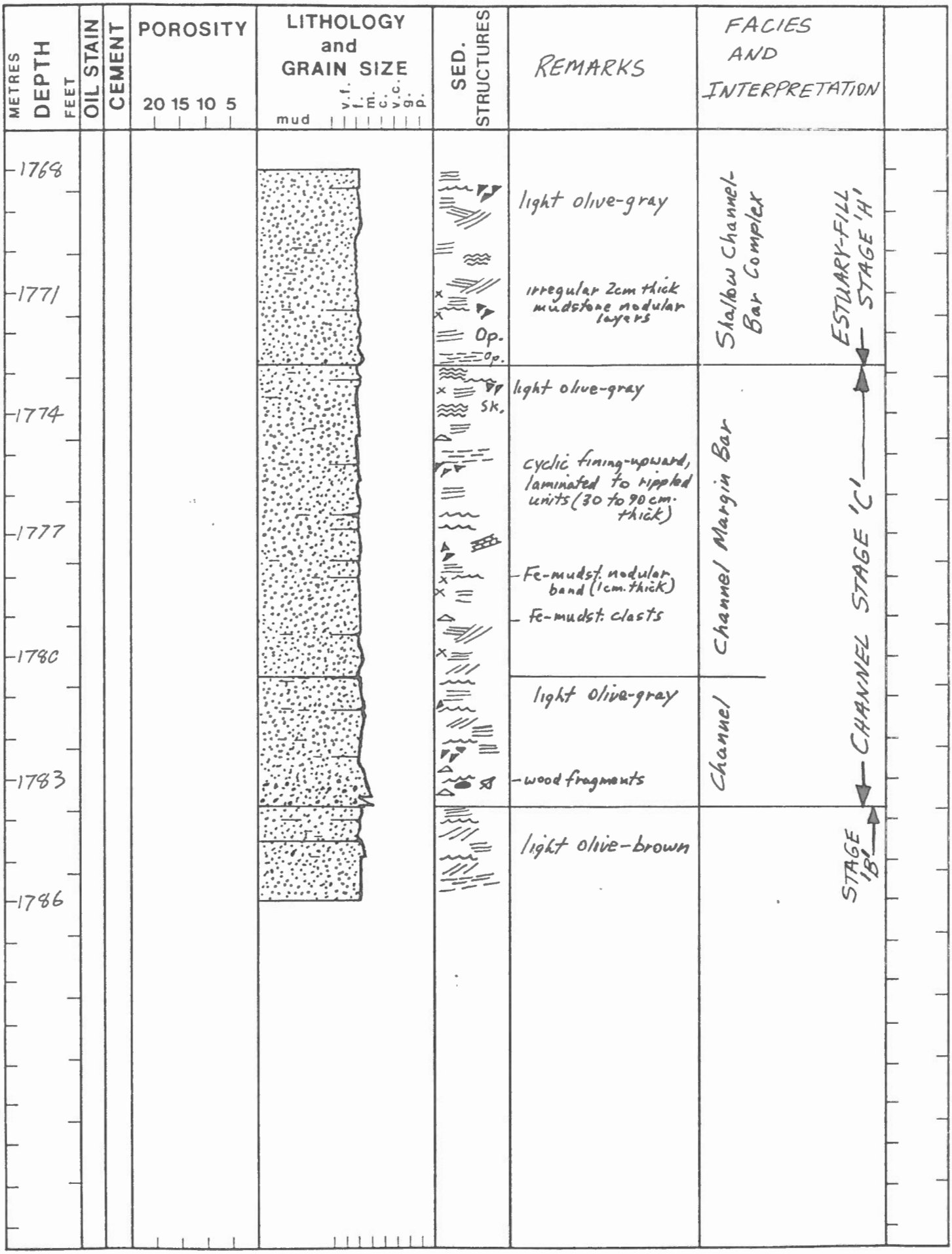
 — BIOTURBATED

 — EXTENSIVELY BIOTURBATED, CHURNED

 — VERTICAL BURROW

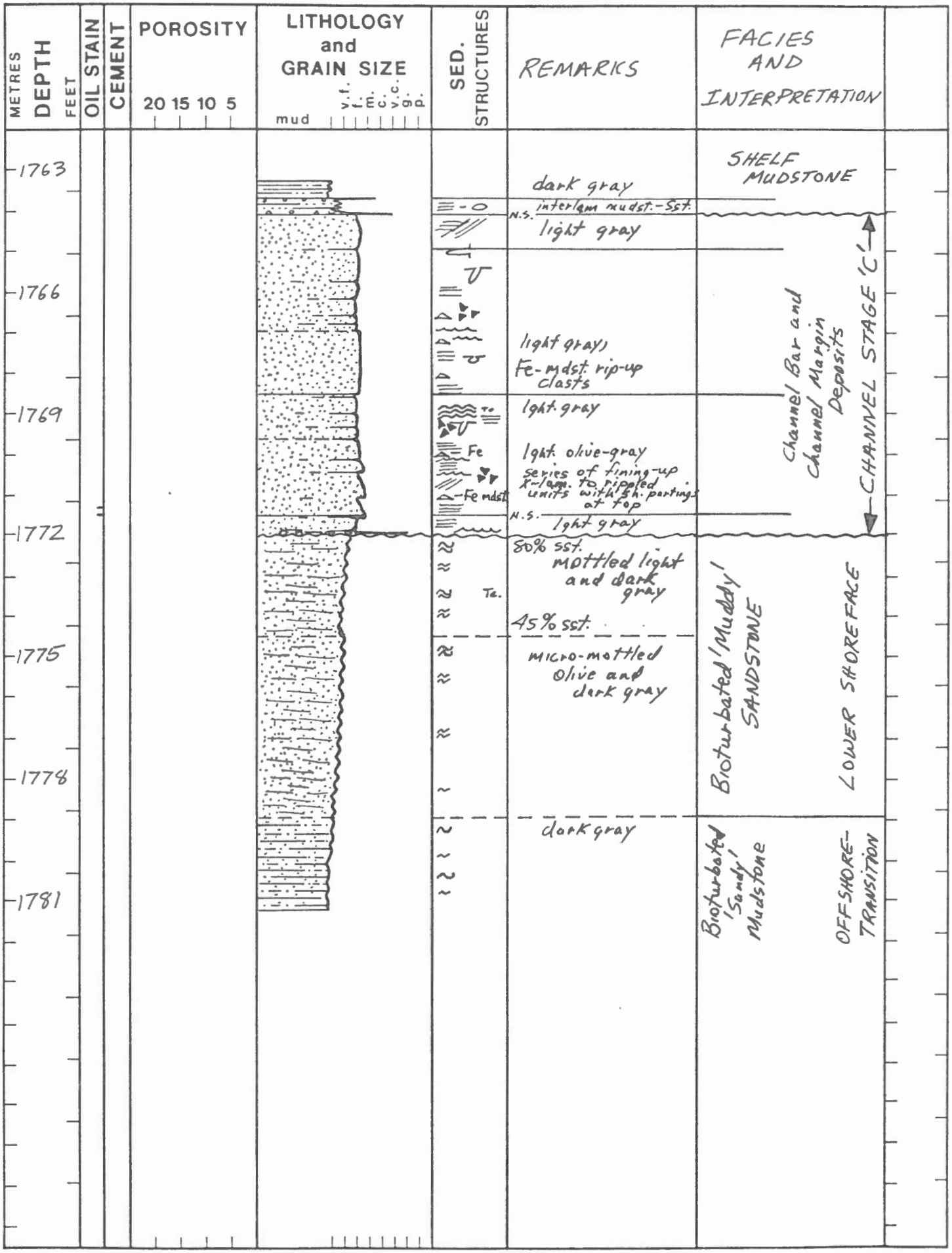
WELL NAME Westcoast et al Crystal (4" diameter, unslabbed)

LOCATION 14-19-45-3W5 CORE INTERVAL 1768-1786 (Rec 18m)



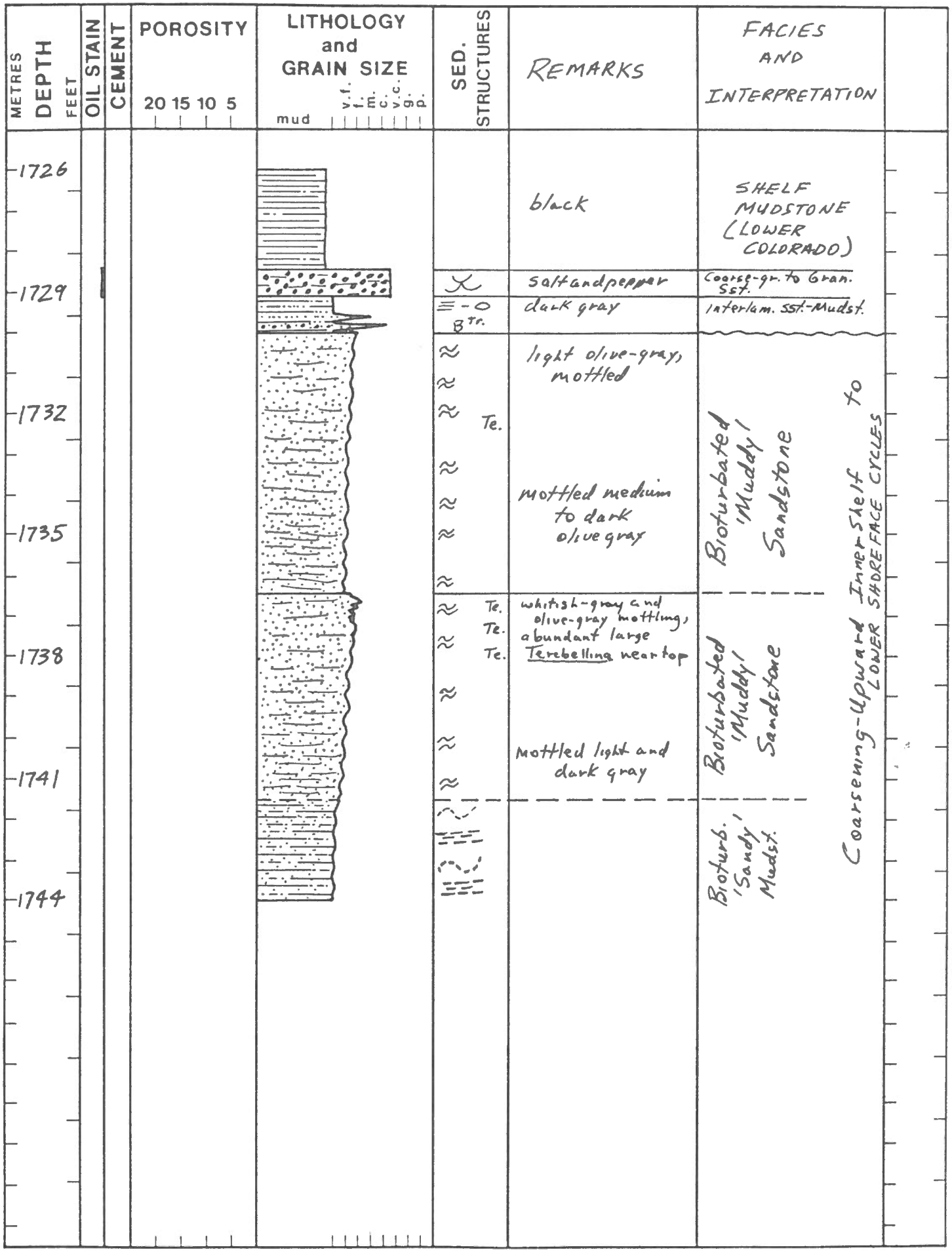
WELL NAME Decalta et al Crystal (4" diameter; unslabbed)

LOCATION 14-20-45-3w5 CORE INTERVAL 1763.25-1781.25 (Rec 18.0 m)



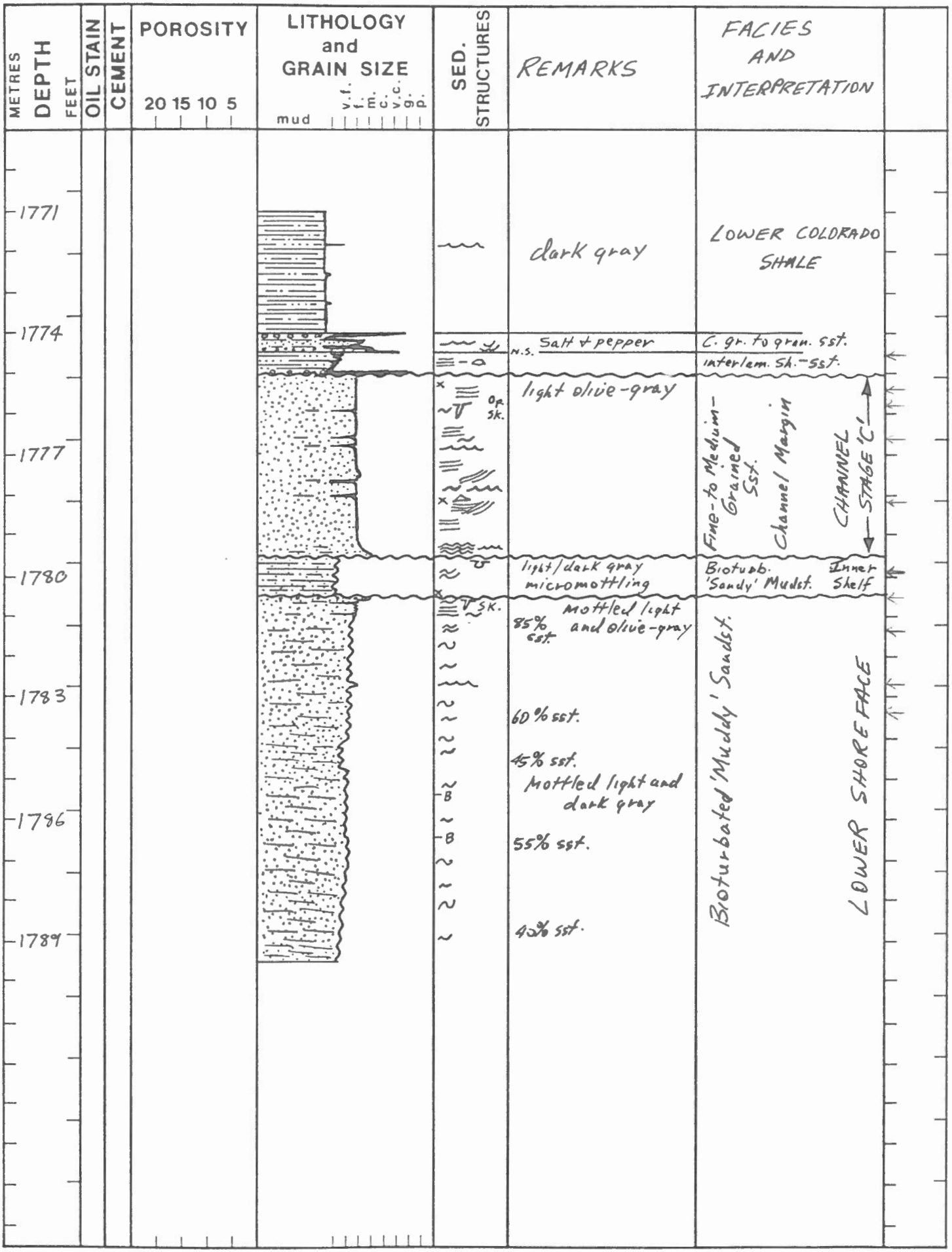
WELL NAME H.B. Headley (10cm diameter, unslabbed)

LOCATION 11-26-45-3W5 CORE INTERVAL 1726-1744



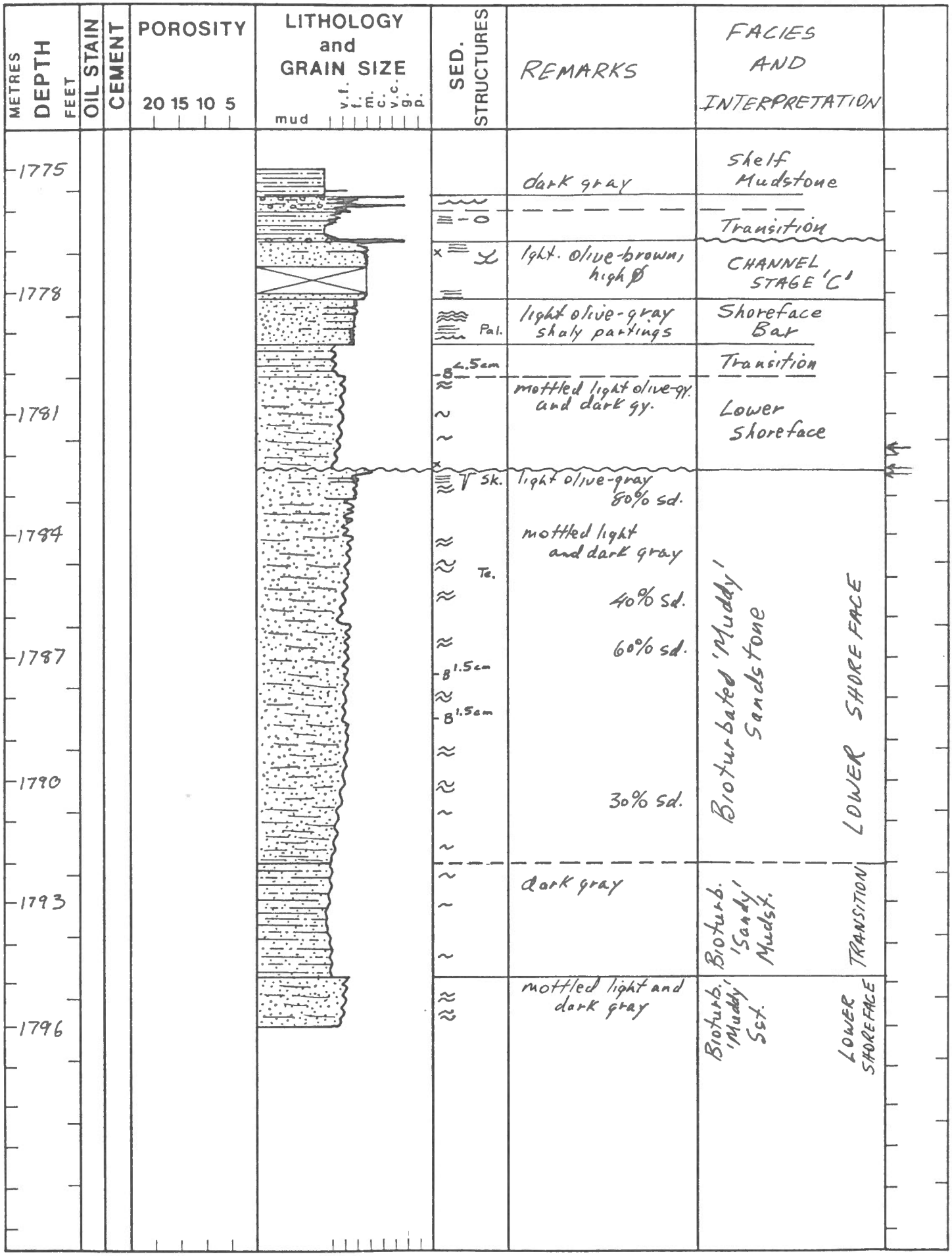
WELL NAME Pumper Crystal (10cm diameter ; slabbed)

LOCATION 6-29-45-3W5 CORE INTERVAL 1771-1789.5 (Rec 18.5)



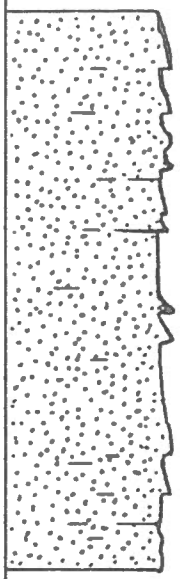
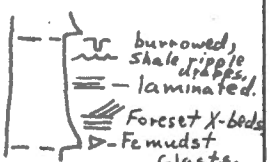
WELL NAME Bumper Crystal (10cm diameter; unslabbed)

LOCATION 14-29-45-3 W5 CORE INTERVAL 1775-1778 (Rec 2.3m)
1778-1796 (Rec 18.0m)



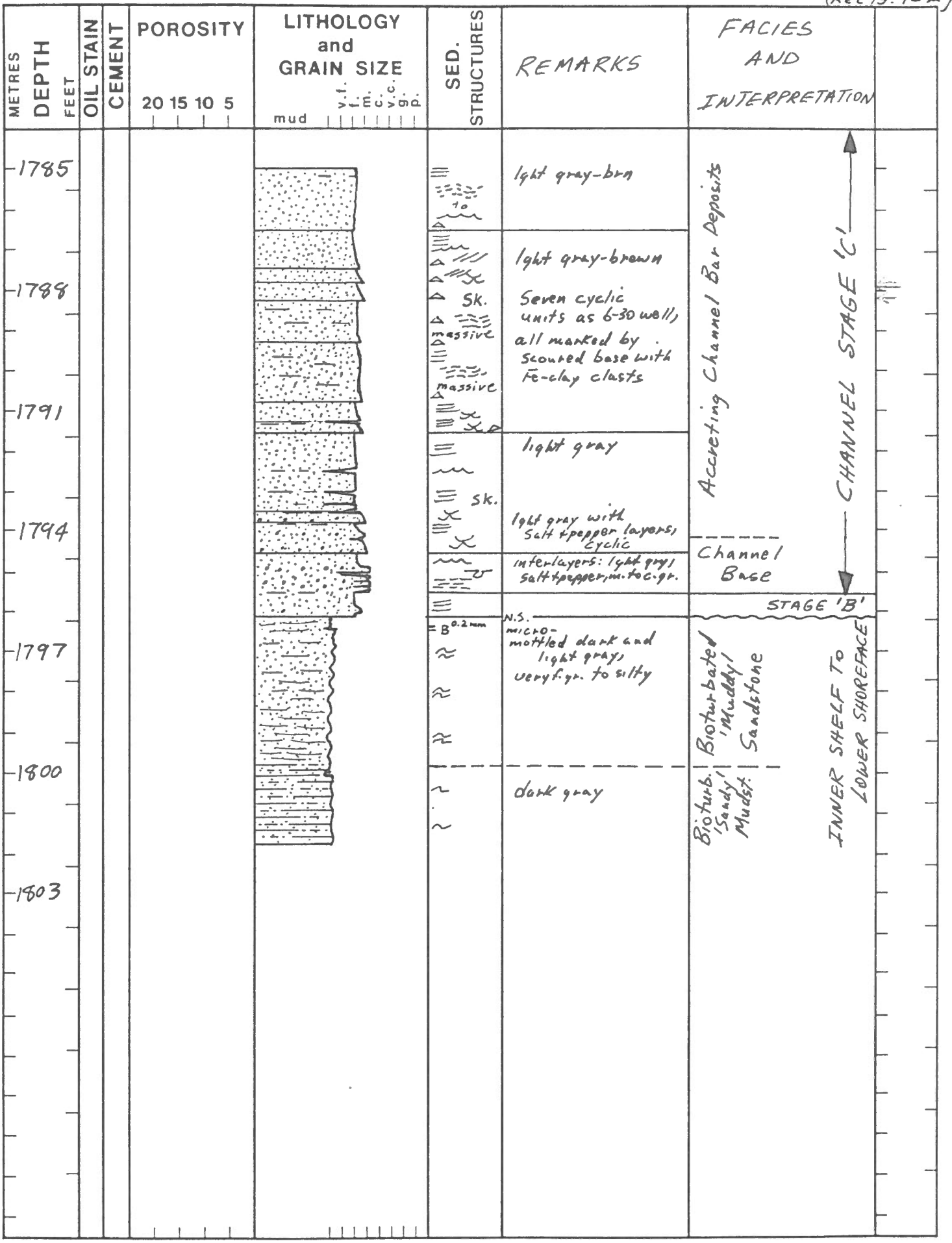
WELL NAME [illegible]

LOCATION 6-30-45-3W5 CORE INTERVAL 1796-1805 (Rec 9.0m)

METRES DEPTH FEET	OIL STAIN	CEMENT	POROSITY 20 15 10 5	LITHOLOGY and GRAIN SIZE mud v.f. f. m. c. v.c. gr. p.	SED. STRUCTURES	REMARKS	FACIES AND INTERPRETATION
1796						light gray cycles as:  (30 to 65 cm. thick)	FINE- TO MEDIUM-GRAINED SANDSTONE CHANNEL STAGE 'C'
1799							
1802							
1805							

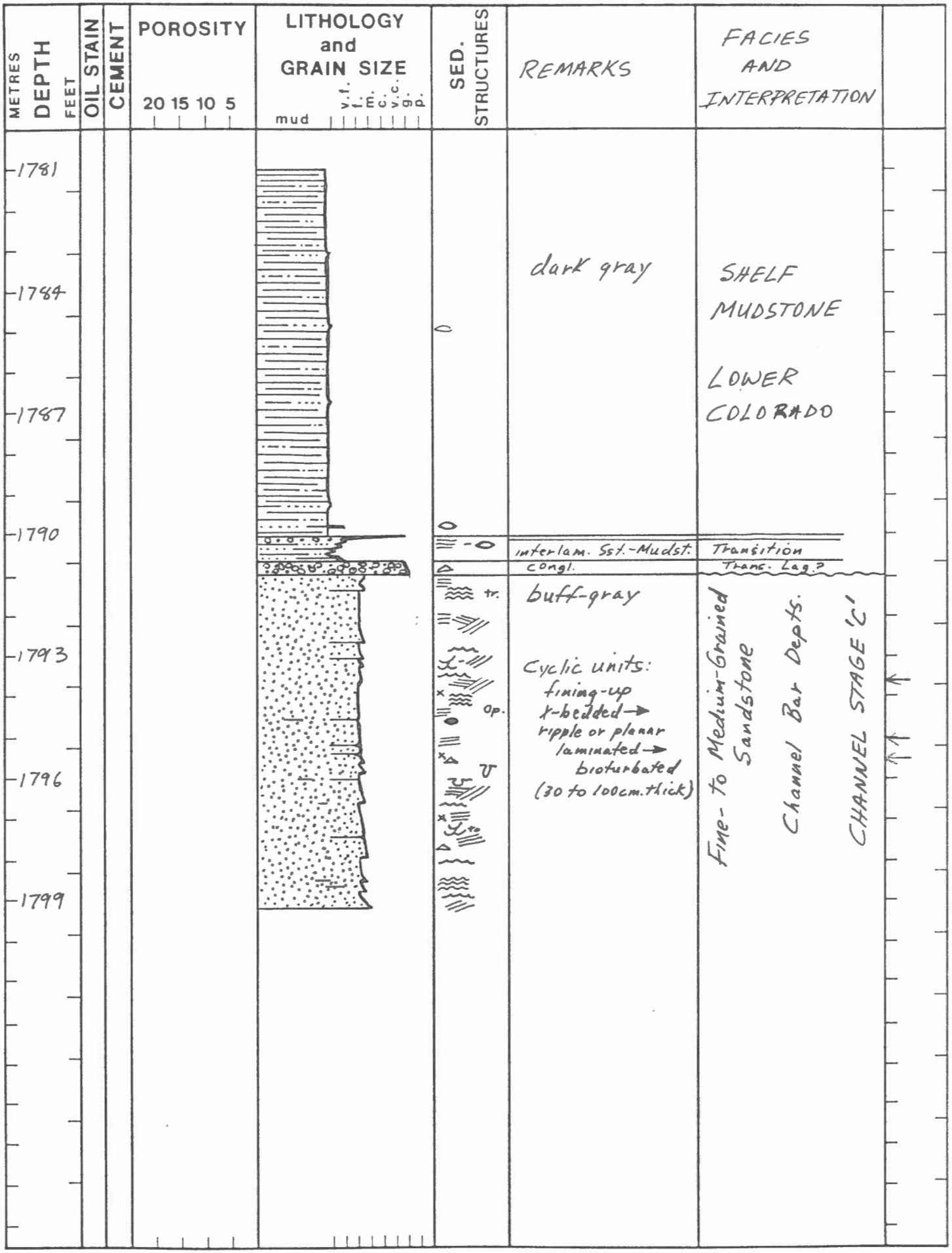
WELL NAME Calcco et al. Crystal

LOCATION 8-30-45-3W5 CORE INTERVAL 1785-1801.75 (Rec 15.95 m)



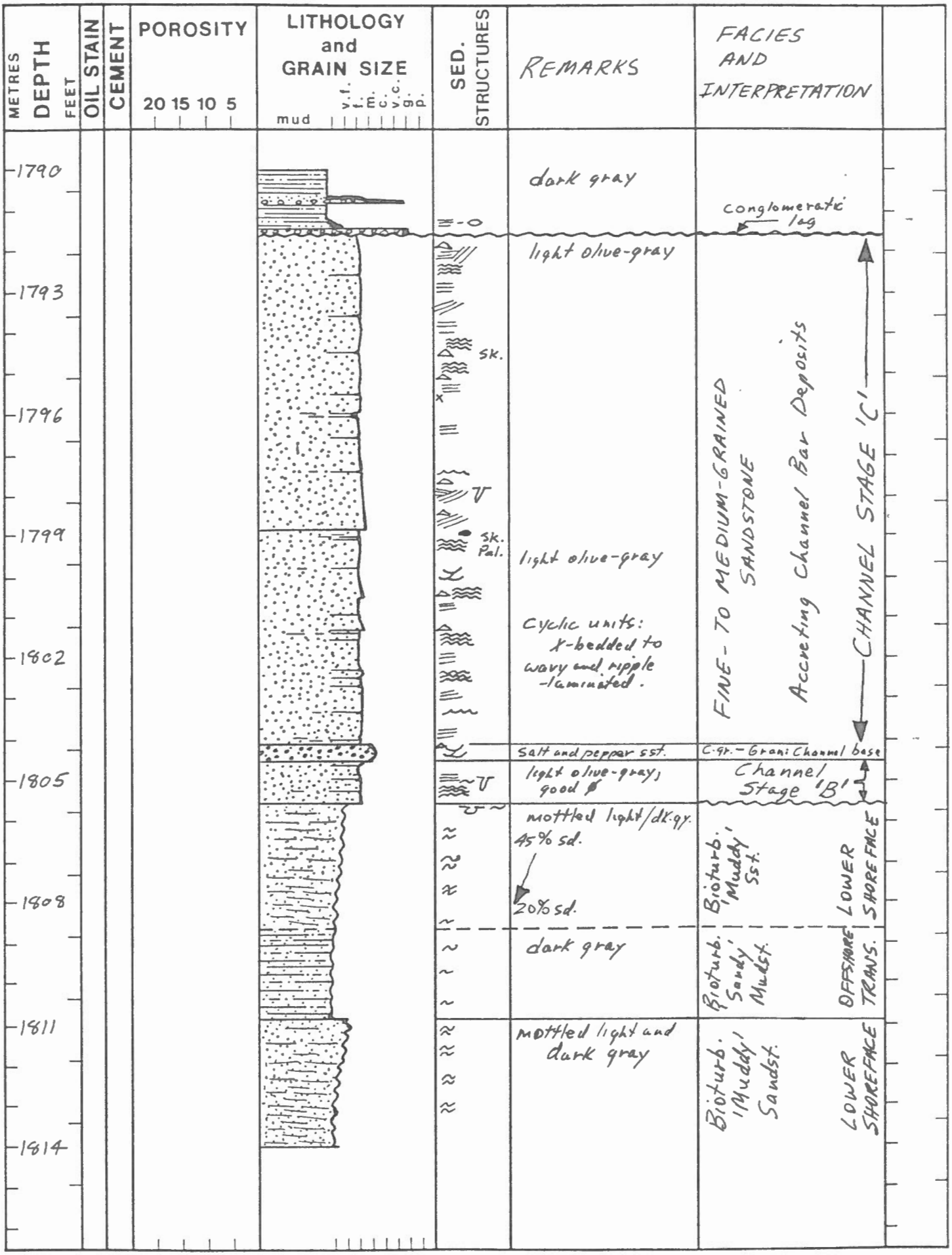
WELL NAME Chietco et al Crystal (10cm. diameter; unslabbed)

LOCATION 16-30-45-3W5 CORE INTERVAL 1781-1799.2 (Rec 18.2)



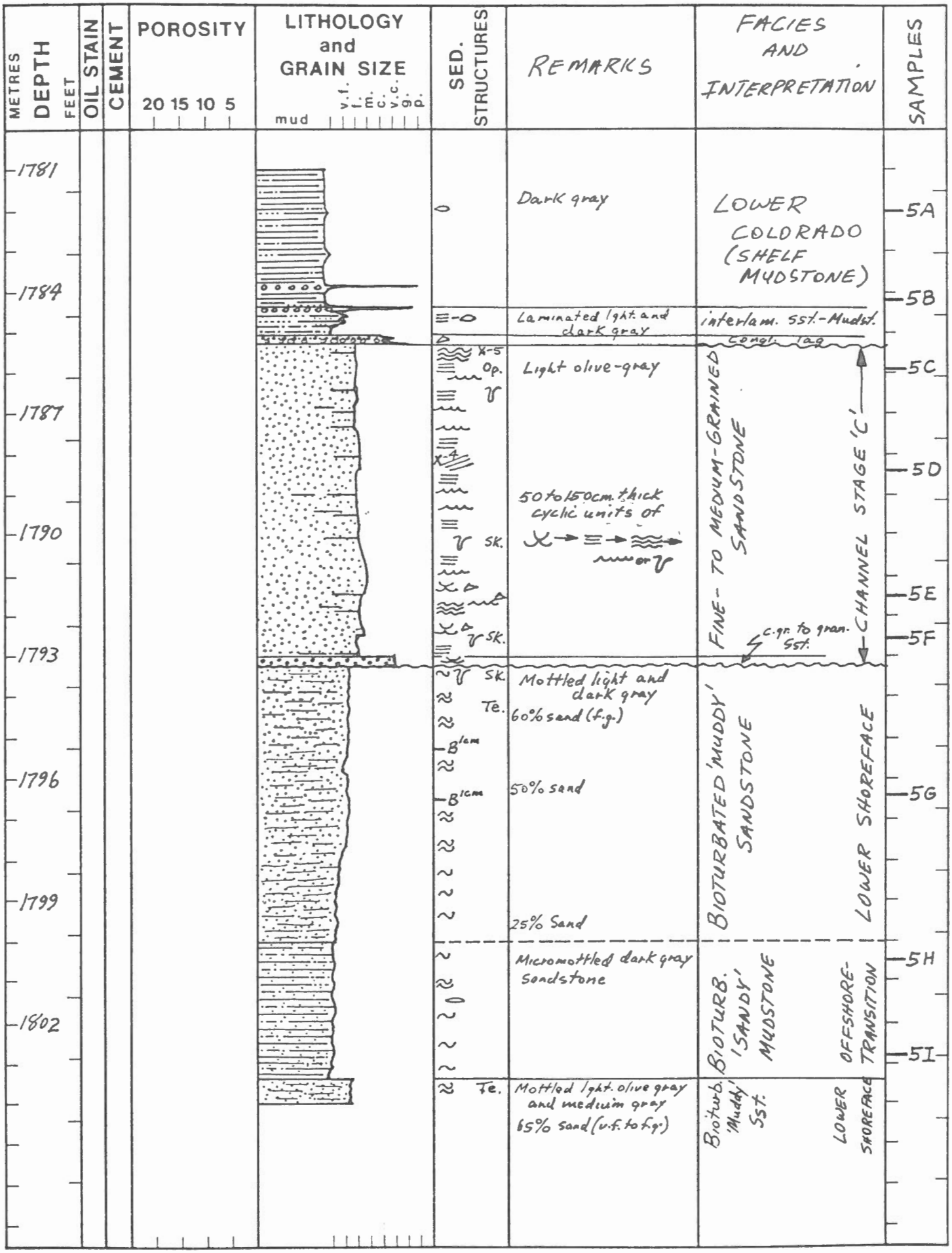
WELL NAME Westcoast et al Crystal (10cm. diameter; unslabbed)

LOCATION 2-31-45-3w5 CORE INTERVAL 1790-1799 (Rec 9.0m)
1799-1814 (Rec 15.0m)



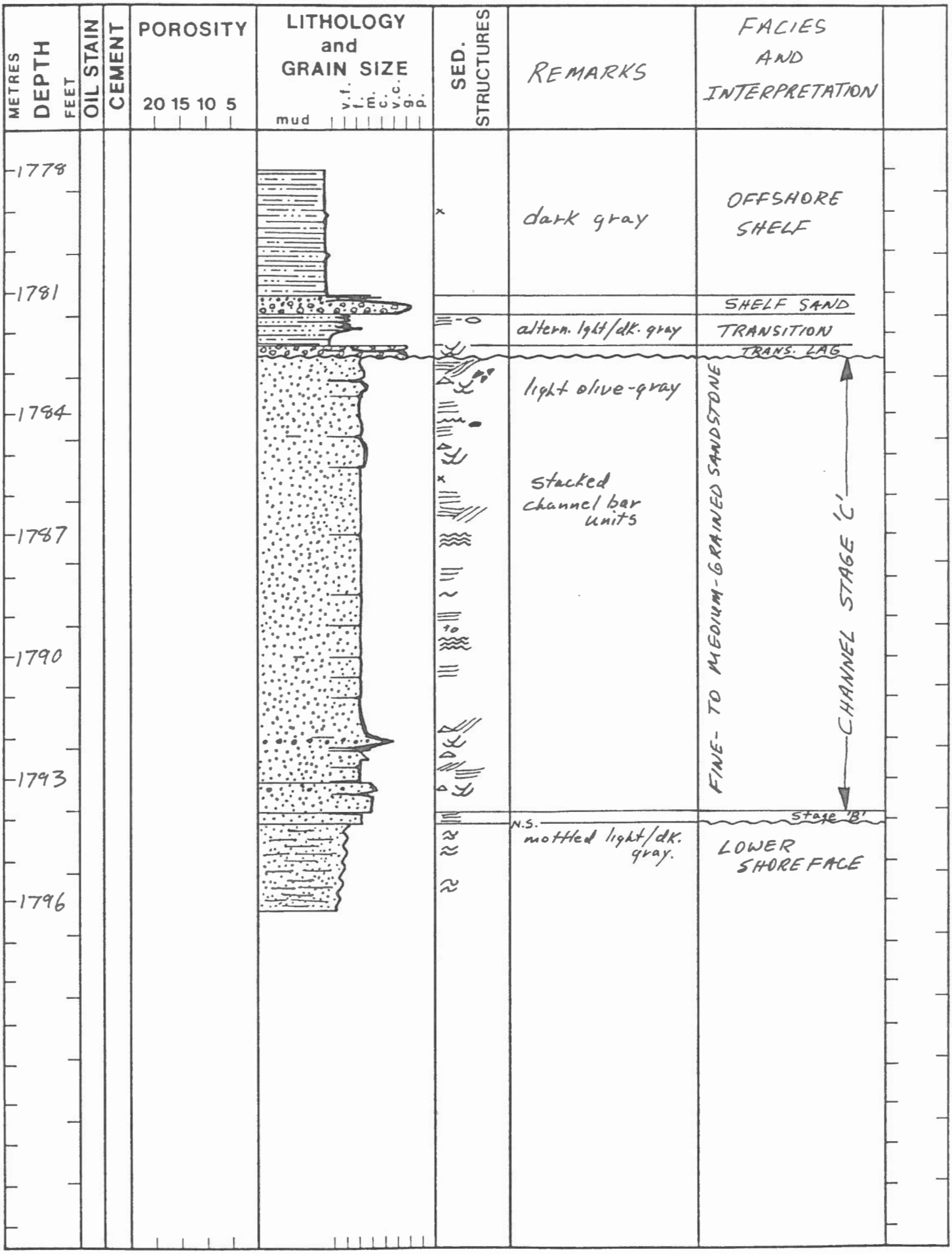
WELL NAME Wesicoast et al Crystal (10cm diameter; unslabbed)

LOCATION 8-31-45-3 w5 CORE INTERVAL 1781-1786 / 1786-1804



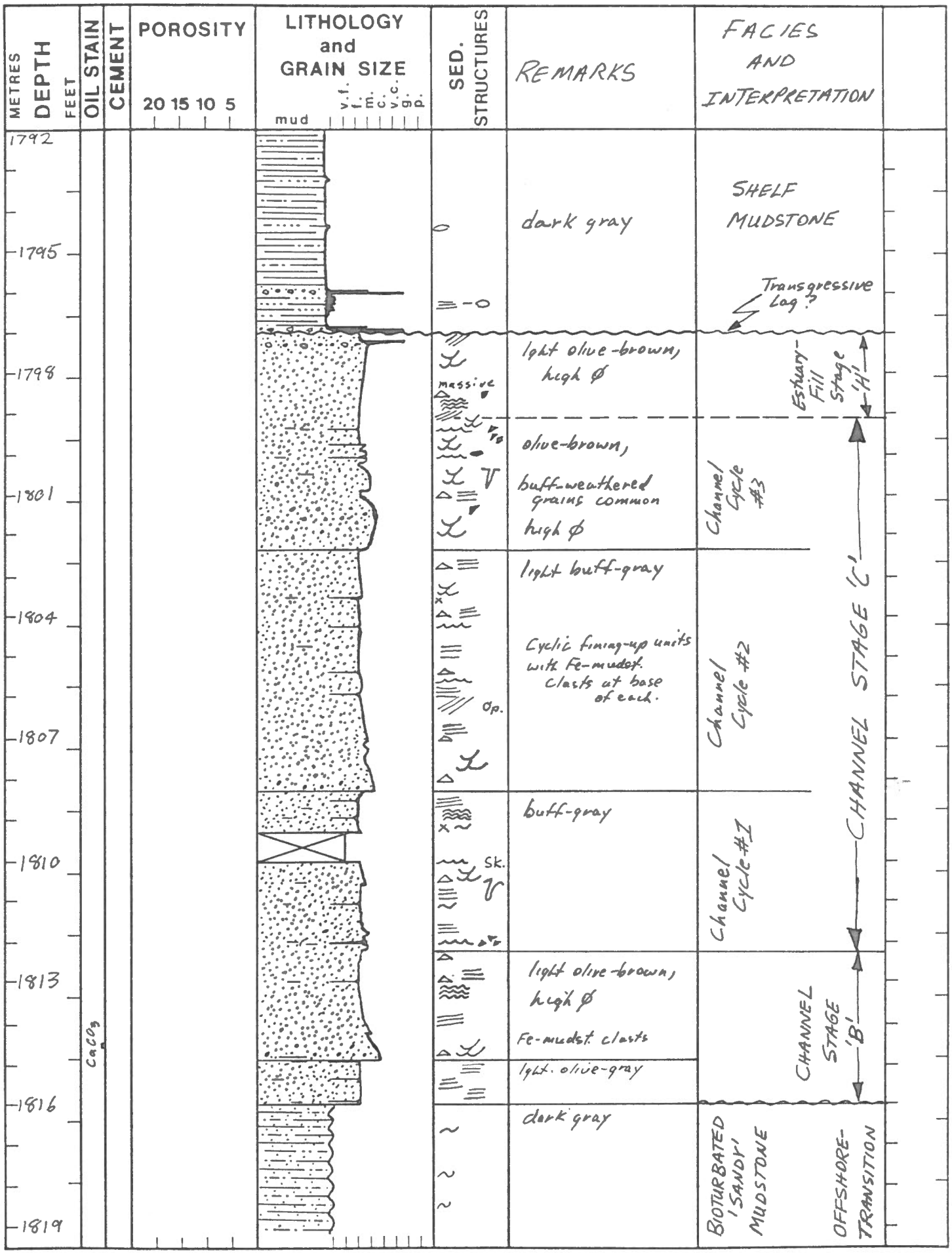
WELL NAME Westcoast et al Crystal

LOCATION 10-31-45-3w5 CORE INTERVAL 1778-1796.2 (Rec 18.2)



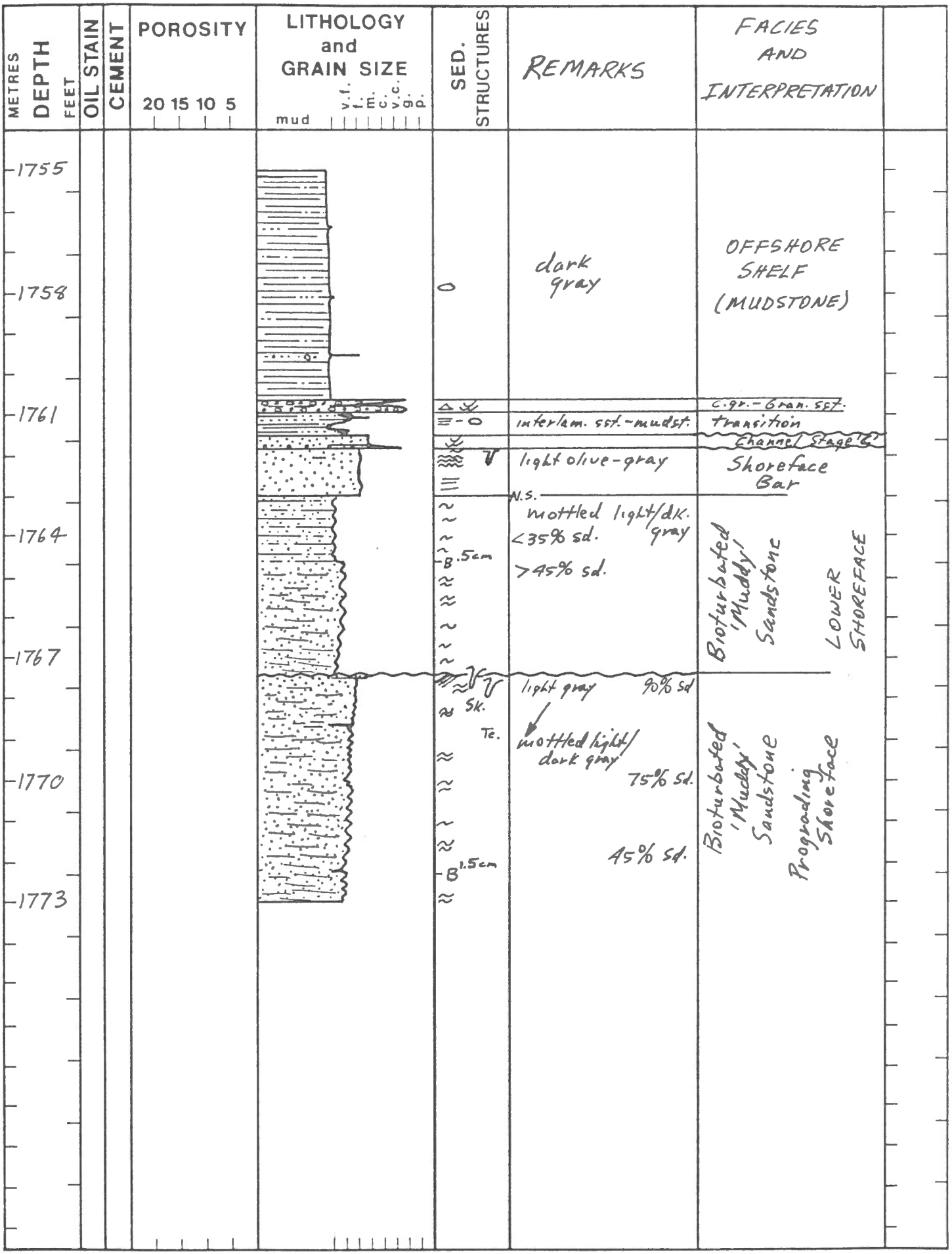
WELL NAME Westcoast et al Crystal (10cm diameter; unslabbed)

LOCATION 12-31-45-3w5 CORE INTERVAL 1792-1810 (Rec 17.25m)
1810-1820 (Rec 9.5m)



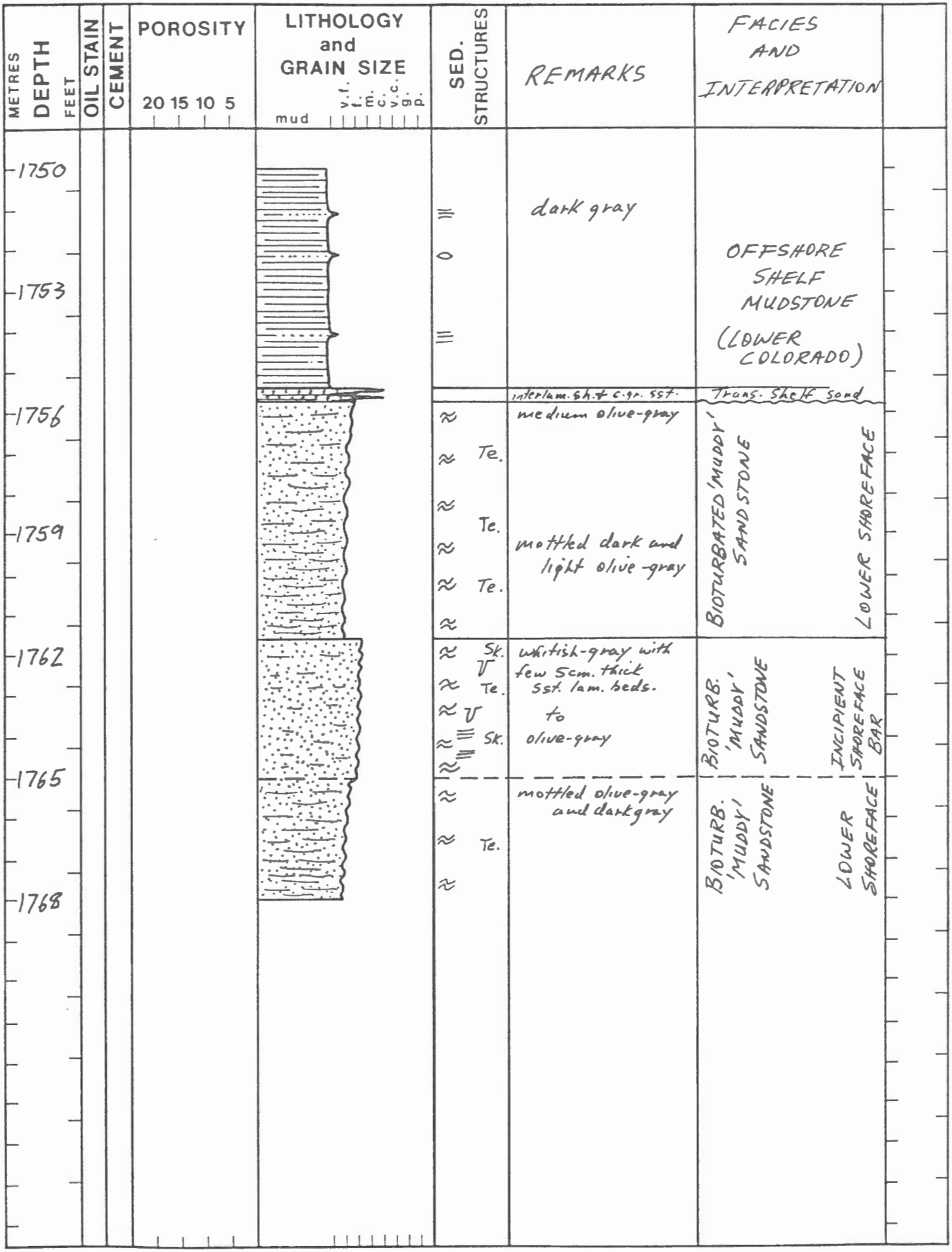
WELL NAME Westcoast et al Crystal (10cm. diameter; unslabbed)

LOCATION 6-32-45-3W5 CORE INTERVAL 1755-1773 (Rec 18m)



WELL NAME Wainoco Rembina (1cm diameter; unslabbed)

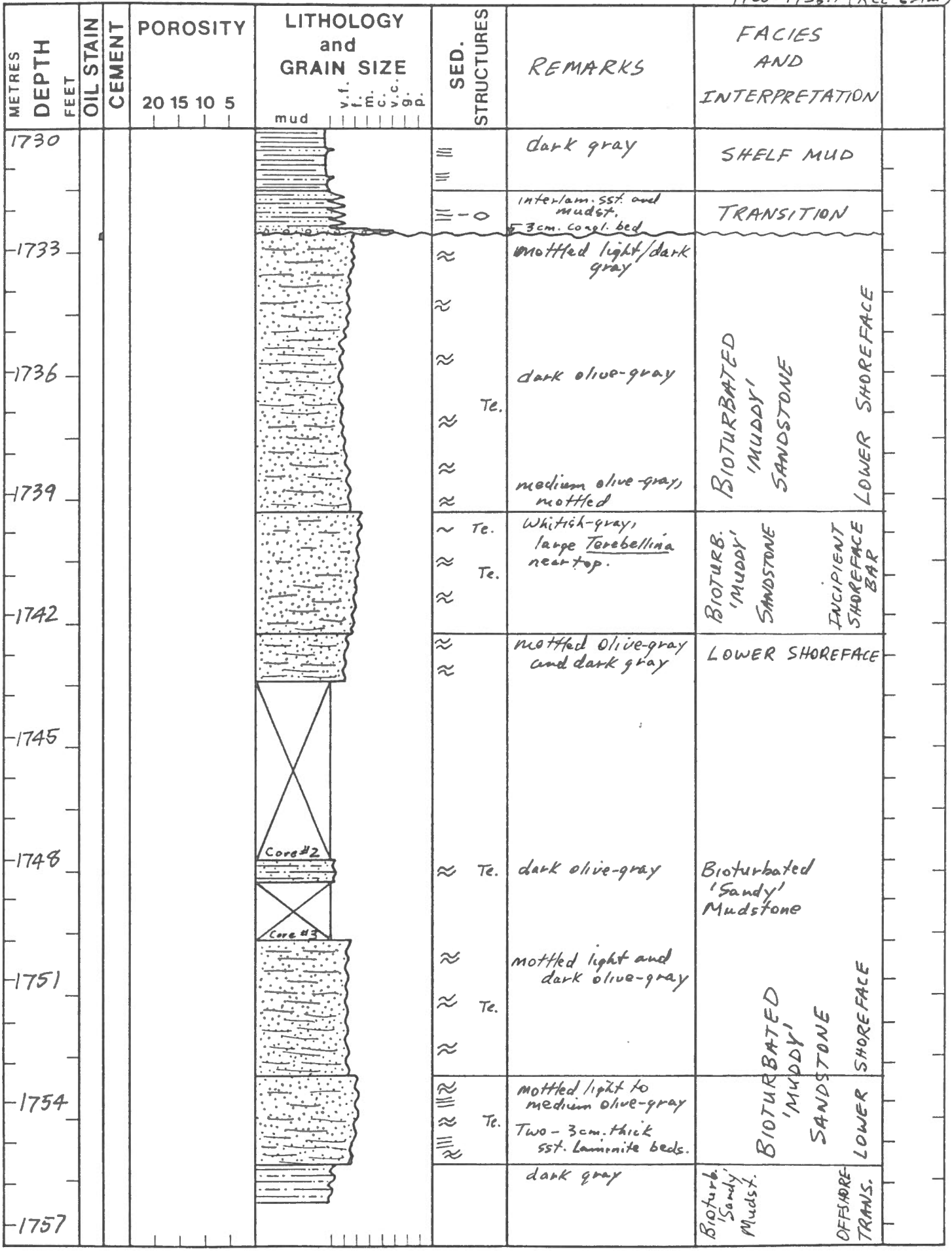
LOCATION 7-32-45-3W5 CORE INTERVAL 1750-1768 (Rec 18m)



WELL NAME Focus et al Wintfield (10cm diameter; slabbed)

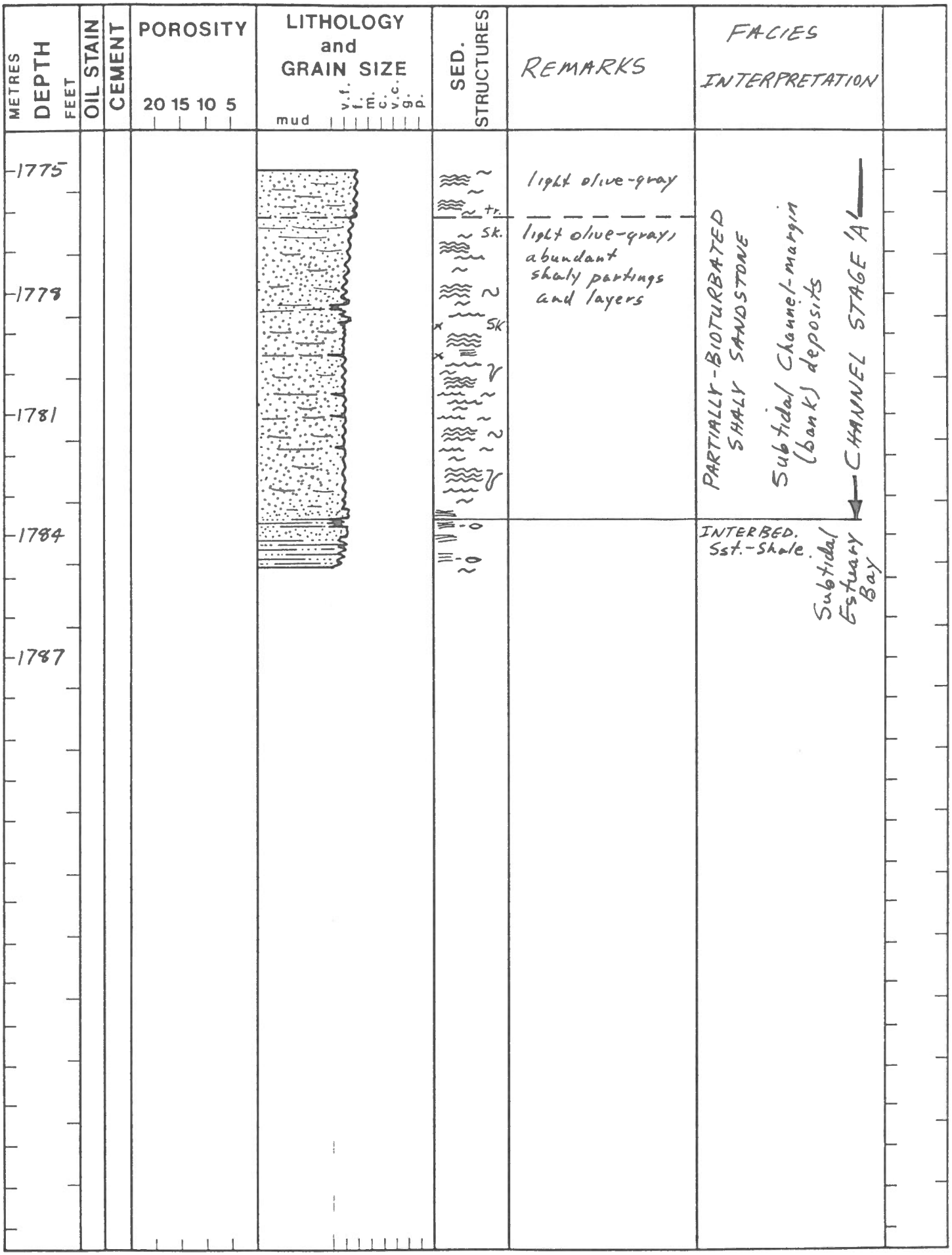
LOCATION 6-34-45-3W5

CORE INTERVAL 1730-1747 (Rec 13.6m)
1748-1748.6 (Rec 0.6m)
1750-1756.4 (Rec 6.4m)



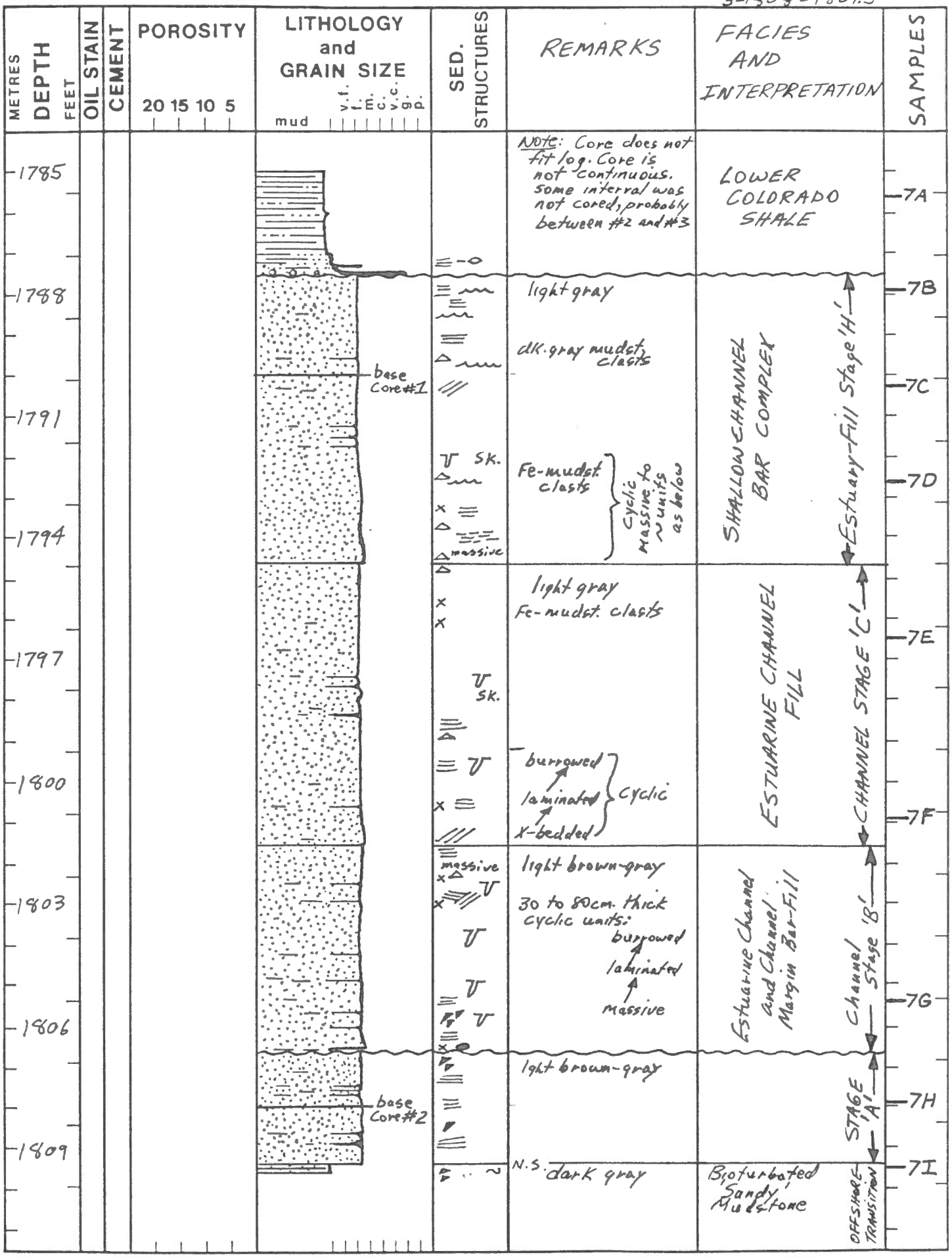
WELL NAME westcoast et al Minhik (10cm diameter, partially slabbed)

LOCATION 16-14-45-4W5 CORE INTERVAL 1775-1784.75 (Rec 9.75)



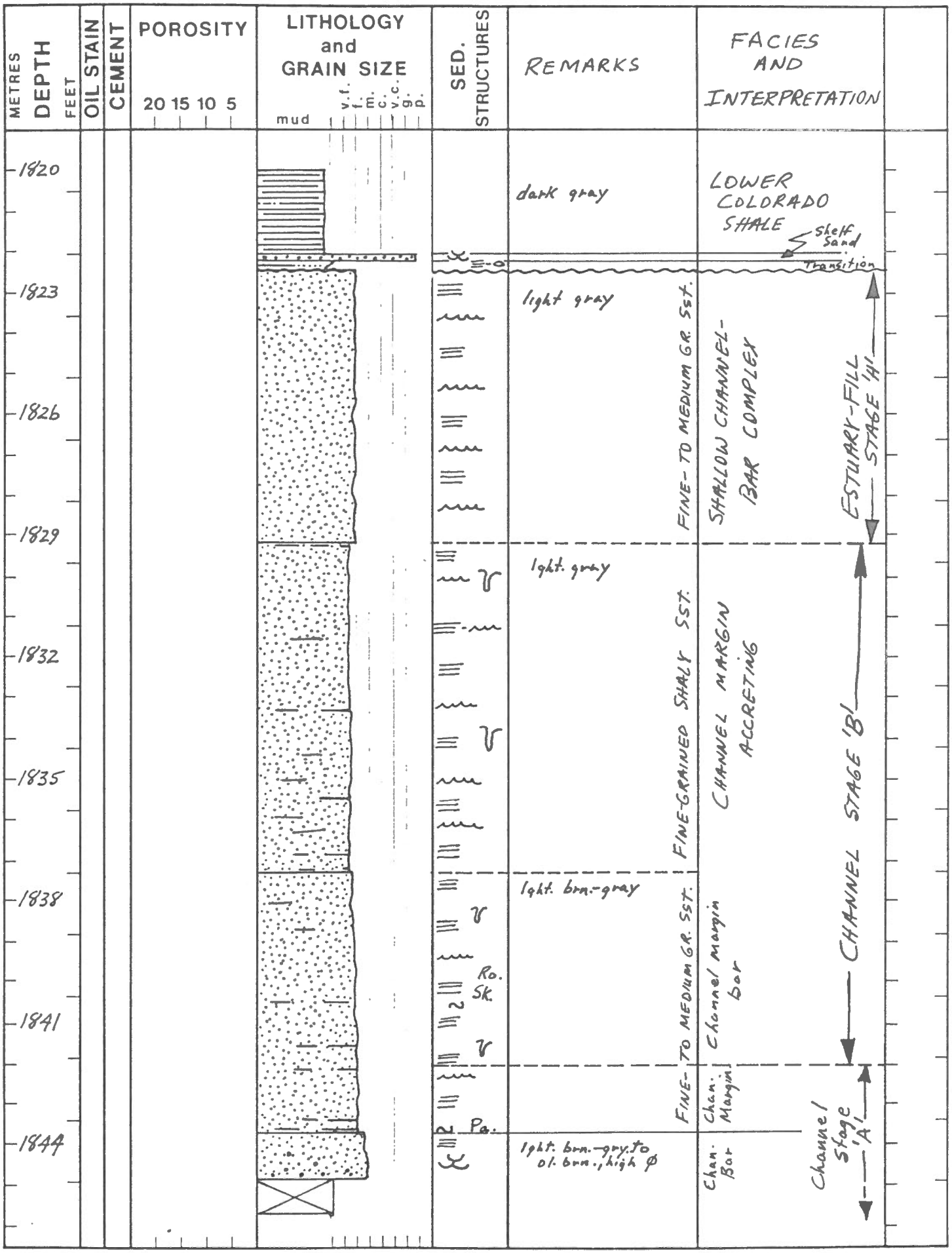
WELL NAME Chiefco et al Crystal (10cm diameter, partially slabbed)

LOCATION 16-24-95-4W5 CORE INTERVAL 1-1785.5-1790
2-1790-1808
3-1808-1809.5



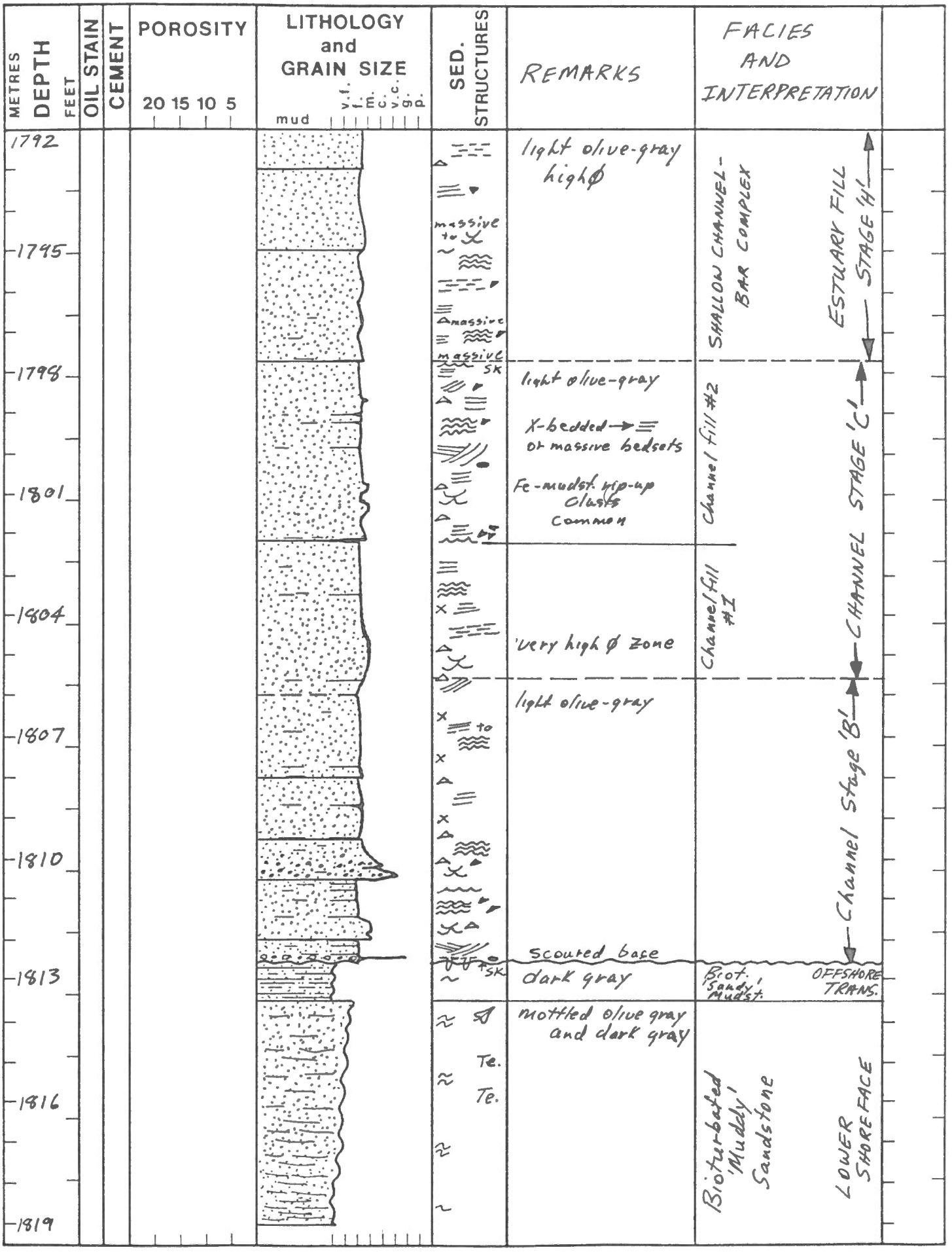
WELL NAME [illegible]

LOCATION 14-25-45-4w5 CORE INTERVAL 1820-1838, 1838-1845.75 (Rec. 6.85)



WELL NAME Pumper Crystal (10cm diameter, unslabbed)

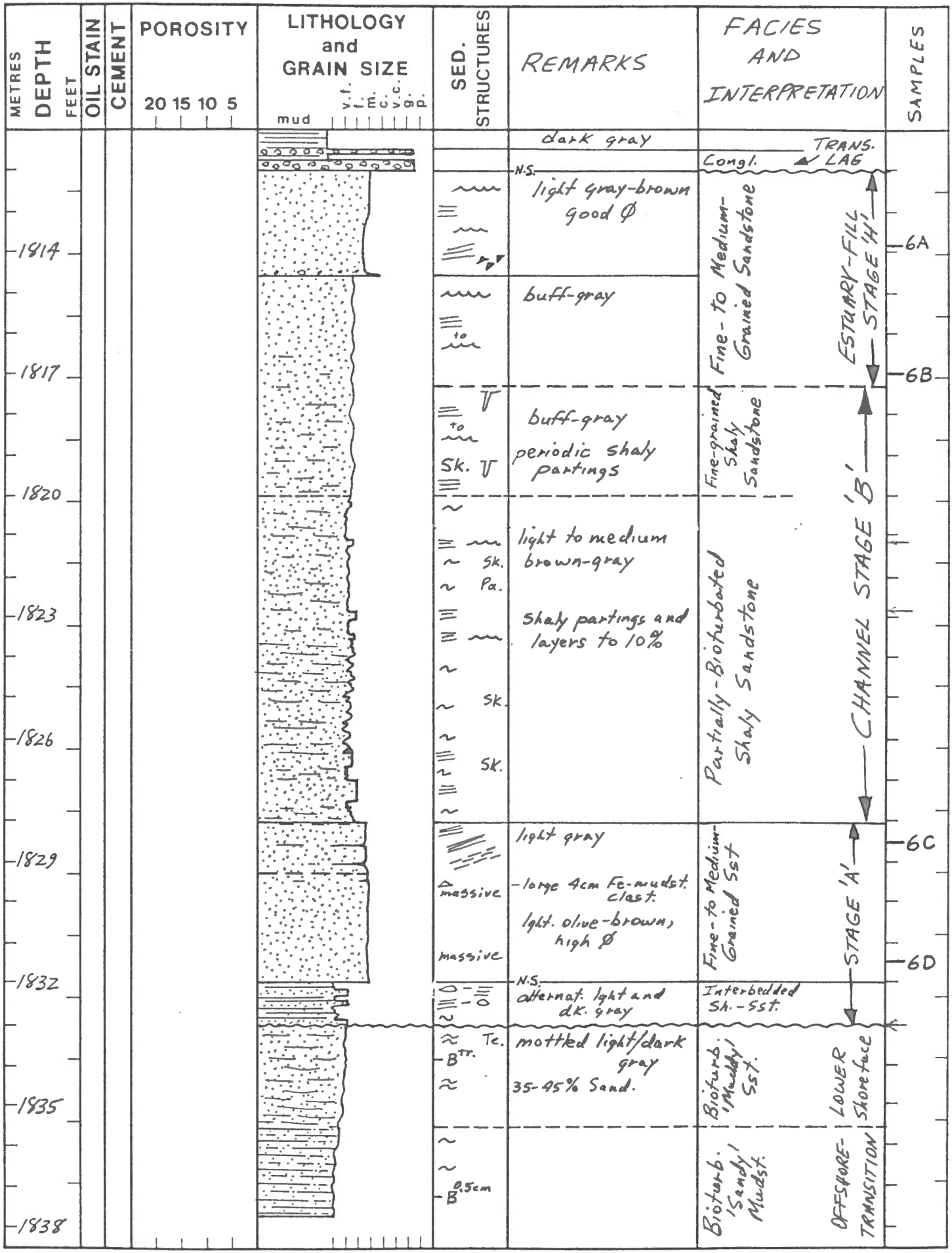
LOCATION 16-25-45-4W5 CORE INTERVAL 1792-1801 (Rec 9m) 1801-1819 (Rec 18m)



WELL NAME [illegible]

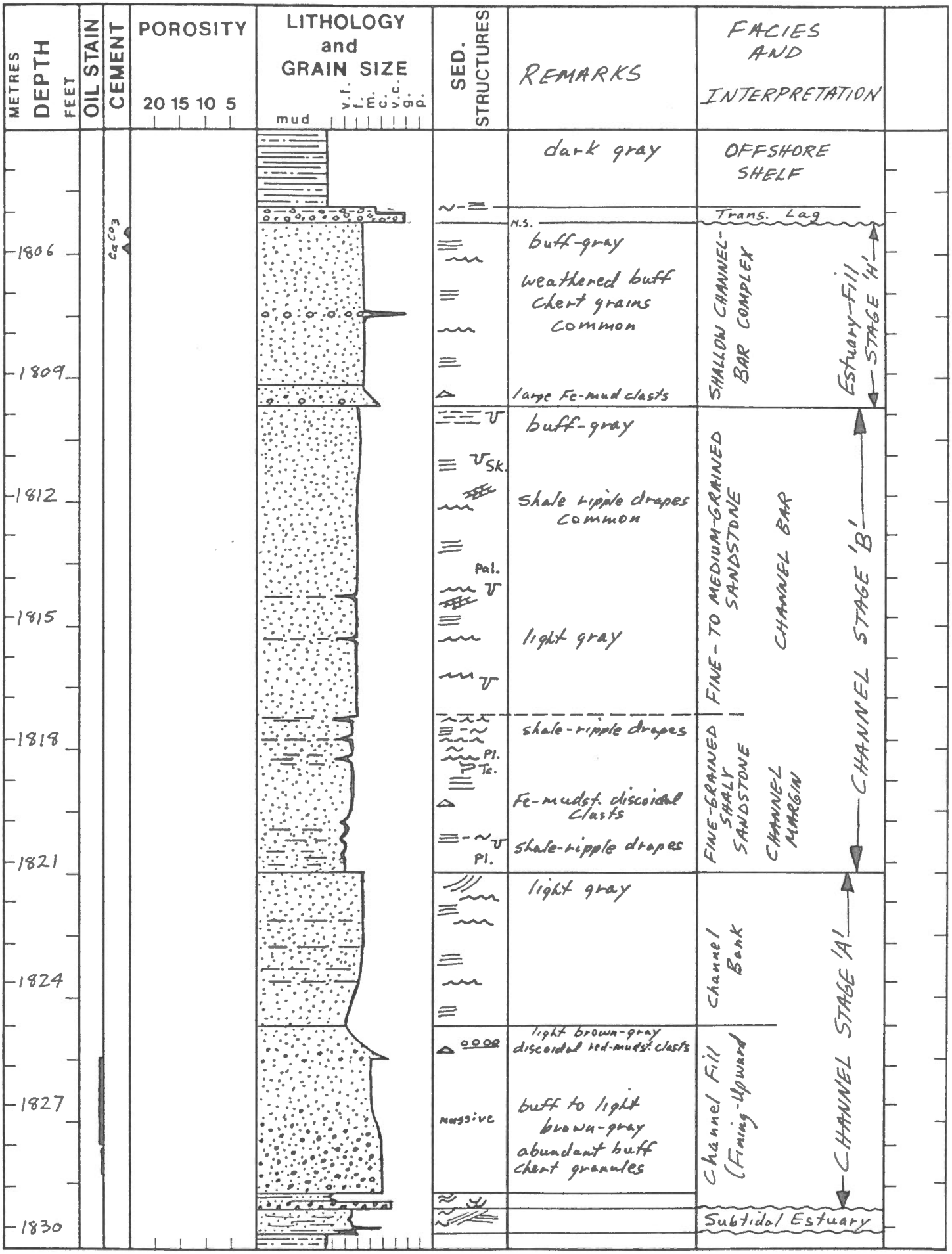
LOCATION 8-26-45-4 w5

CORE INTERVAL 1809-1827.25 (Rec. 18.5)
1827.25-1837.25 (Rec. 10.2)



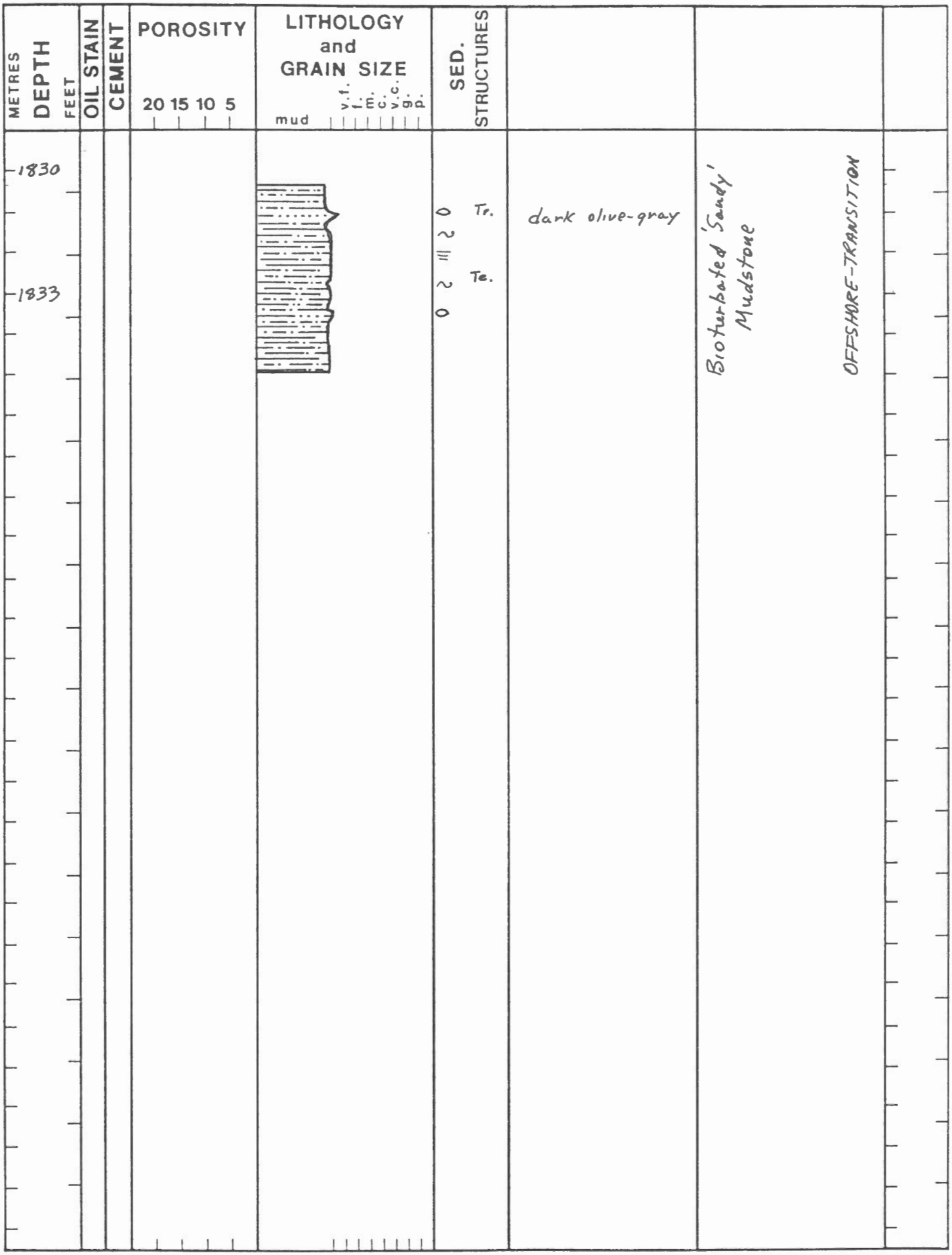
WELL NAME Petrocan Murphy Crystal (4' diameter; fairly broken up)

LOCATION 6-36-45-4W5 CORE INTERVAL 1803-1834.95m



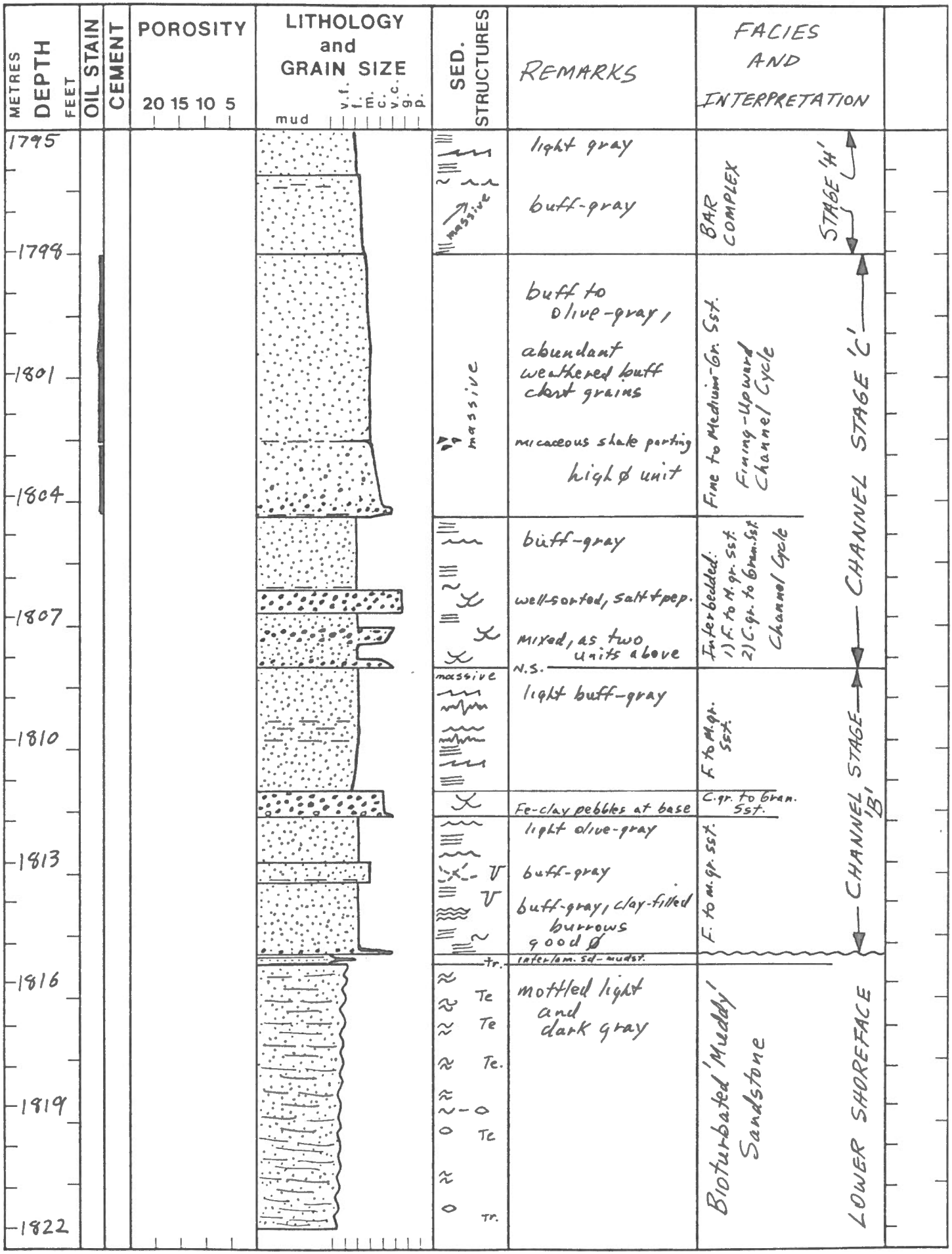
WELL NAME Petrocan Murphy Crystal

LOCATION 6-36-45-4 w5 CORE INTERVAL 1803-1834.95



WELL NAME Petrocon Murphy Crystal (10cm diameter, core broken)

LOCATION 8-36-45-4W5 CORE INTERVAL 1795-1813 / 1813-1826 (Rec 12.5m)



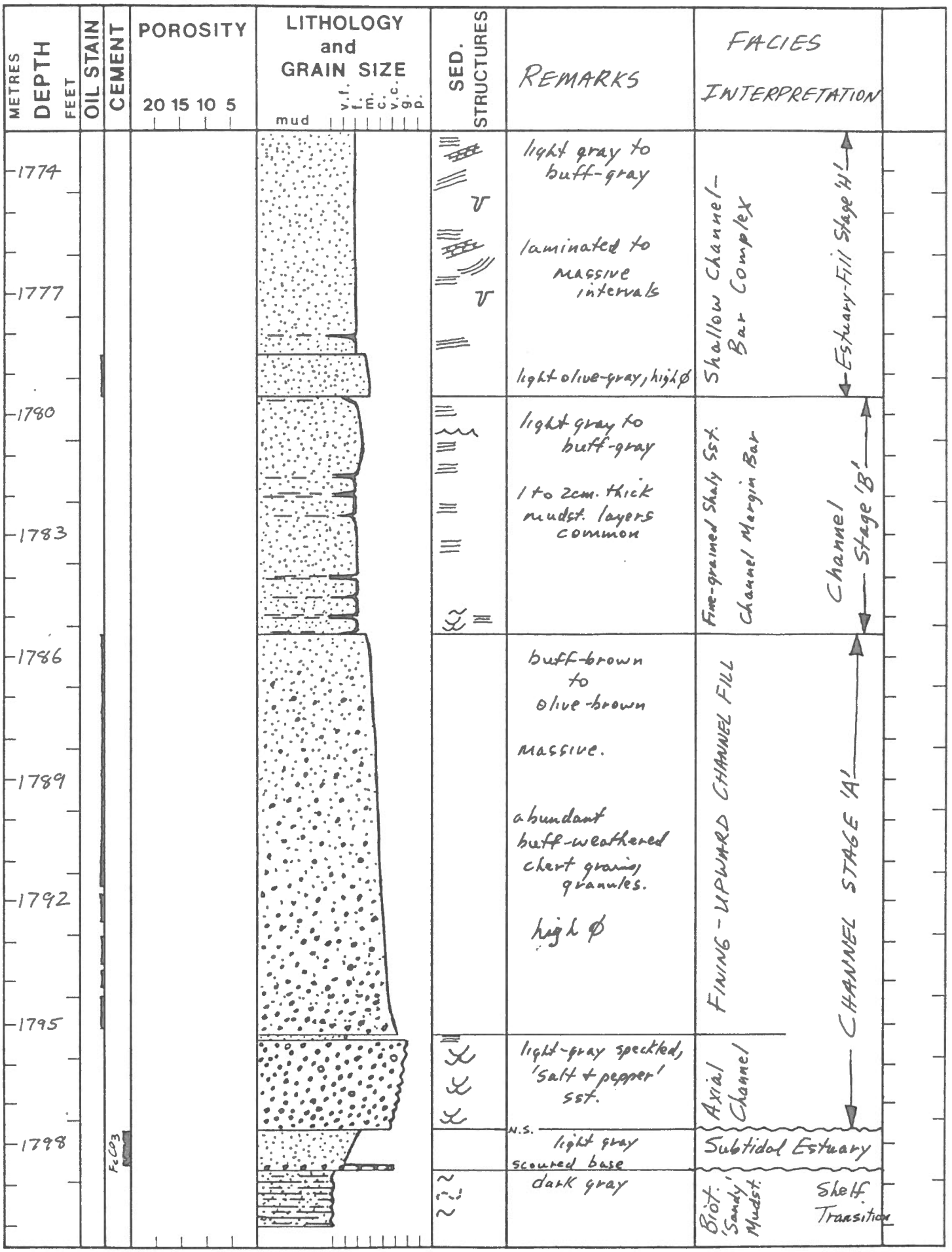
WELL NAME Petrocon Murphy Crystal (continued)

LOCATION 8-36-45-4W5 CORE INTERVAL 1795-1813 / 1813-1826

METRES DEPTH FEET	OIL STAIN	CEMENT	POROSITY 20 15 10 5	LITHOLOGY and GRAIN SIZE (mud, v.f., f., m., c., v.c., g., p.)	SED. STRUCTURES			
1822					tr.	mottled	Biot. 'Muddy' Sst.	Coarsening-up; L. offshore; Lower Shoreface
						dark brown-gray	Biot. 'Sandy' Mudst.	
1825					Te.	mottled light/dk. gy.	Biot. 'Muddy' Sst.	Lower Shoreface
1828								

WELL NAME Petrocon Murphy Crystal

LOCATION 14-36-45-4W5 CORE INTERVAL 1773-1791; 1791-1800



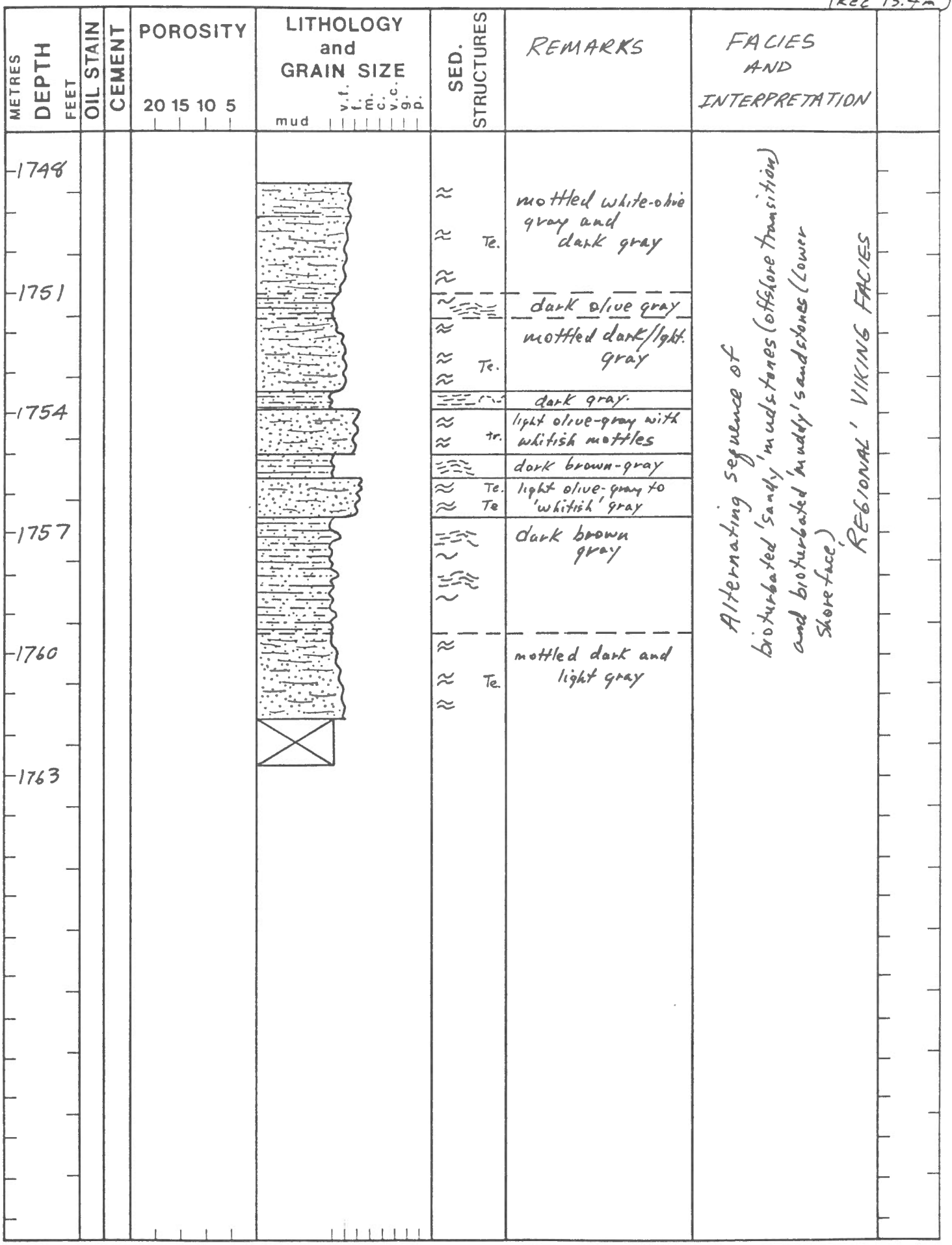
WELL NAME Focus et al Winfield (10cm diameter, slabbed)

LOCATION 13-5-46-3W5 CORE INTERVAL 1731-1749 (Rec 18m)
1749-1763 (Rec 4.75m)
1763-1771 (Rec 7.75m)

METRES DEPTH FEET	OIL STAIN	CEMENT	POROSITY 20 15 10 5	LITHOLOGY and GRAIN SIZE mud v.f. f. m. c. v.c. g. p.	SED. STRUCTURES	REMARKS	FACIES AND INTERPRETATION
1743						dark gray	SHELF (Lower Colorado) Shale)
1746						interlaminated sdst.-mudst.	Transition Trans. log
1749		SiO2			St.	light-gray (glauconitic)	Coarsening-up Lower Shoreface to Shoreface Bar
1752						mottled medium and dark olive-gray	
1755					Te. Sp.	mottled whitish-gray and olive-gray (glauconitic)	Bioturbated Muddy Sandstone LOWER SHOREFACE
1758					B 0.5cm. B 0.5cm.	mottled medium and dk. olive gray (glauconitic)	
1761						Note: Core intervals are not properly labelled with respect to log depths. See Figure 7 for adjusted core depths.	
1764						dark olive-gray 'micromottling'	Bioturbated 'Sandy' Mudstone (OFFSHORE-TRANSITION)
1767						very shaly	
1770					Te.	mottled med. to dk. olive-gray to dark olive-gray to base	LOWER SHOREFACE TRANSITION

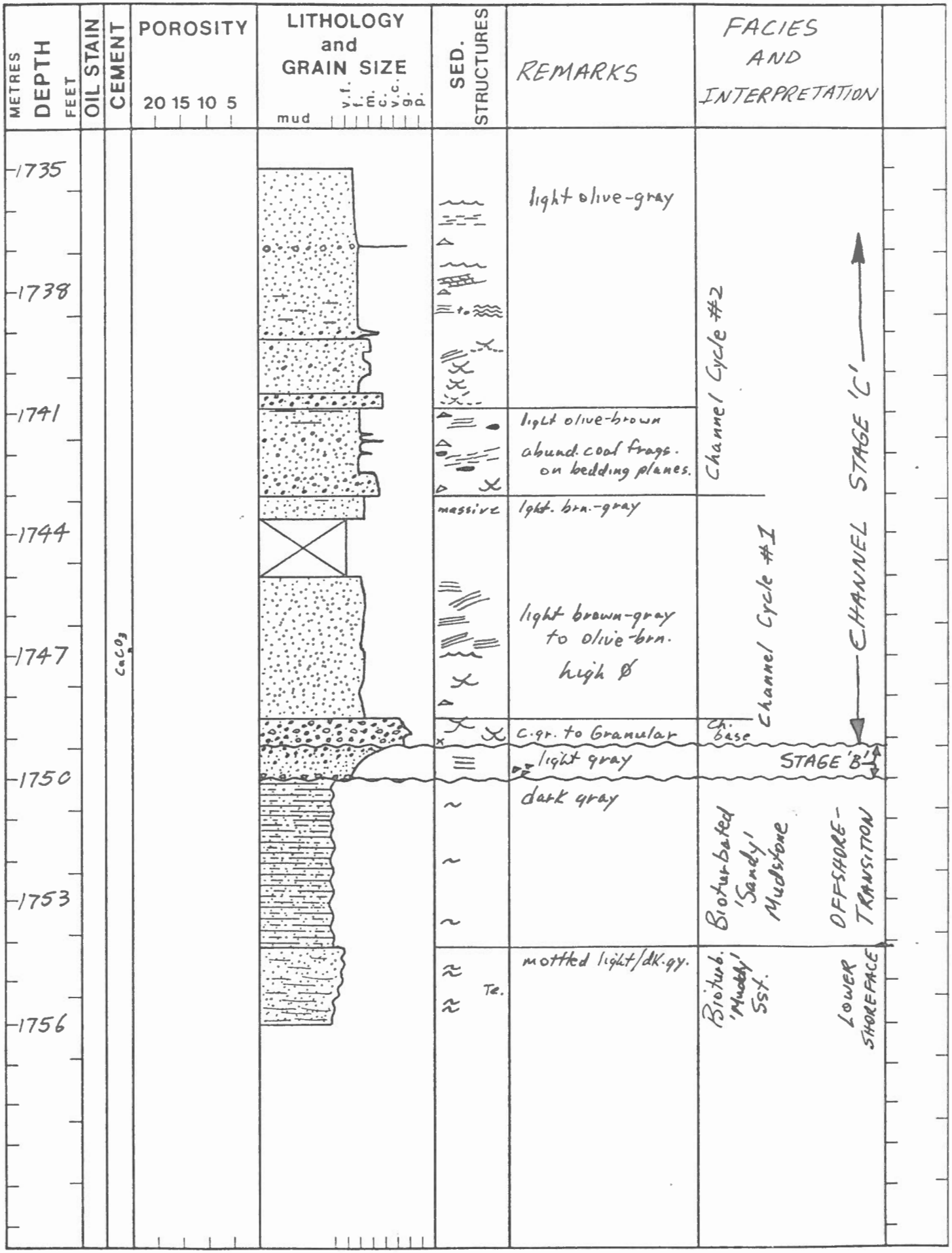
WELL NAME P.D. U. Gas Redwing (1cm diameter; unslabbed)

LOCATION 16-5-46-3W5 CORE INTERVAL 1748.25-1762.75 (Rec 13.4m)



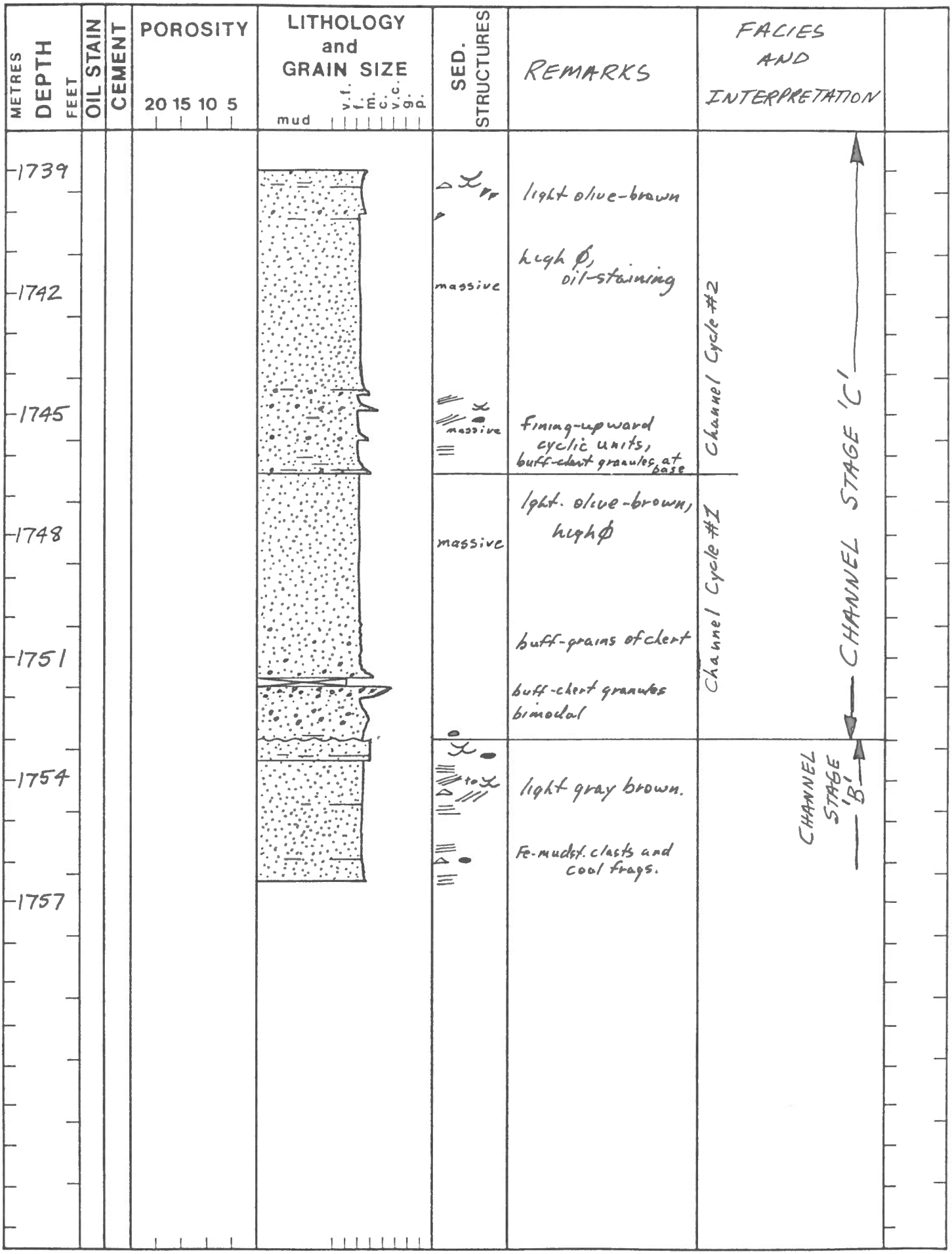
WELL NAME Westcoast et al. remdiag (10cm diameter; unslabbed)

LOCATION 6-6-46-3 W5 CORE INTERVAL 1735-1744 (Rec 8.7m)
1745-1756 (Rec 11.2m)



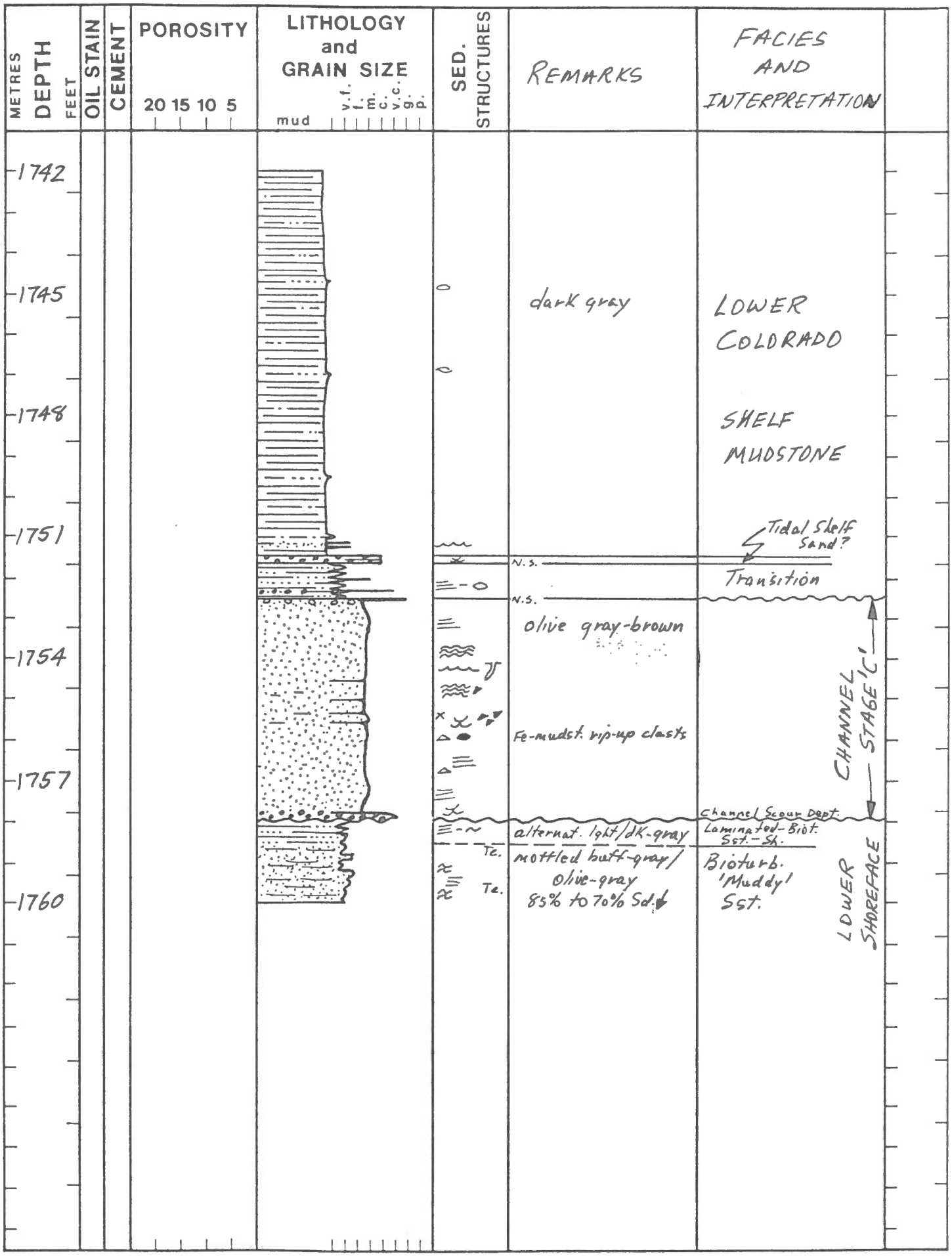
WELL NAME Pluesky et al Pembina

LOCATION 11-6-46-3W5 CORE INTERVAL 1739-1757 (Rec 17.4 m)



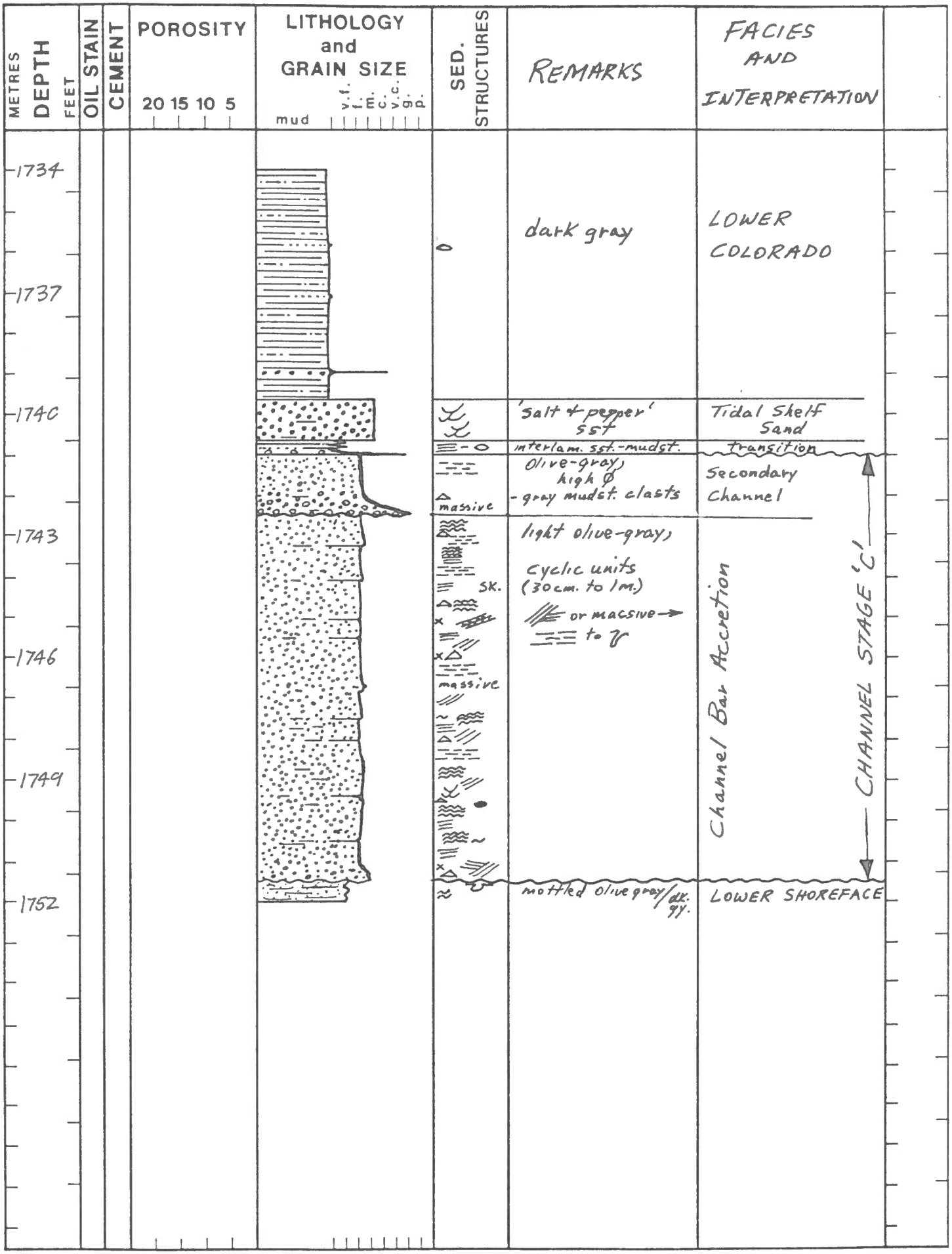
WELL NAME Dilesky et al Winfield (8cm diameter; unslabbed)

LOCATION 16-6-46-3W5 CORE INTERVAL 1742 - 1760 (Rec 18m)



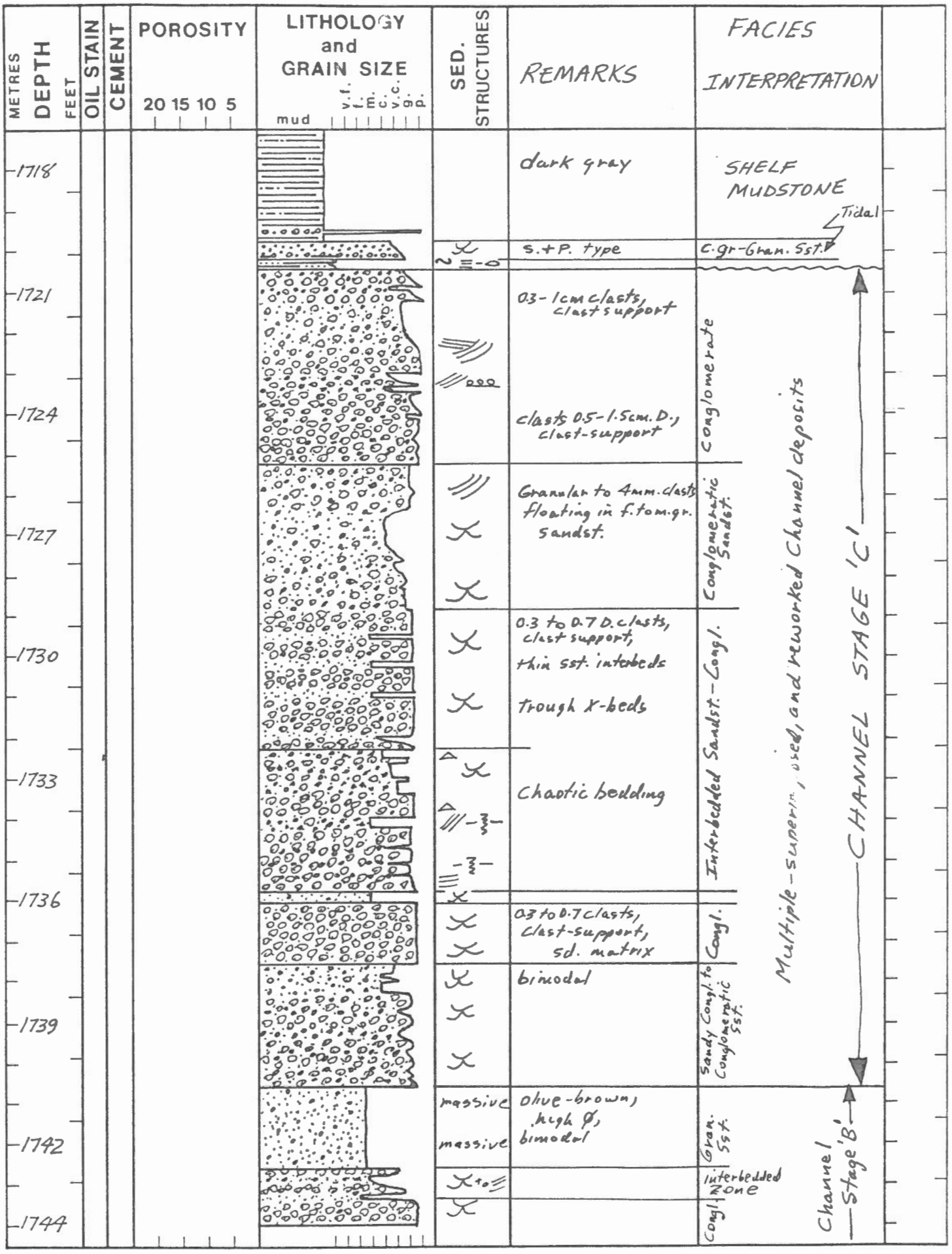
WELL NAME West Coast et al Crystal (10cm diameter; partially slabbed)

LOCATION 2-7-46-3w5 CORE INTERVAL 1734-1752 (Rec 18m)



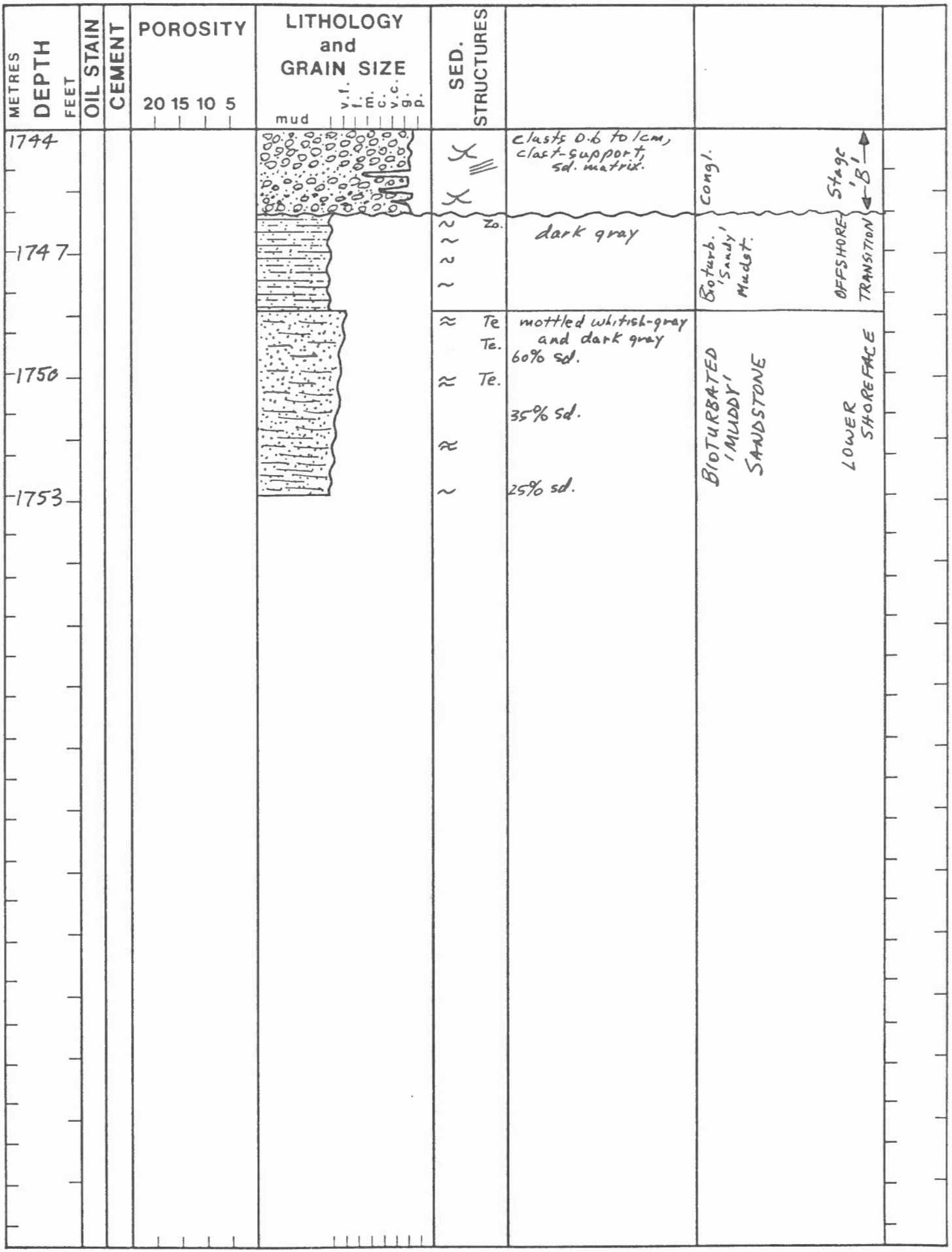
WELL NAME West Coast et al. Crystal (10cm. diameter, unslabbed)

LOCATION 4-7-46-3 w5 CORE INTERVAL 1717-1735, 1735-1753



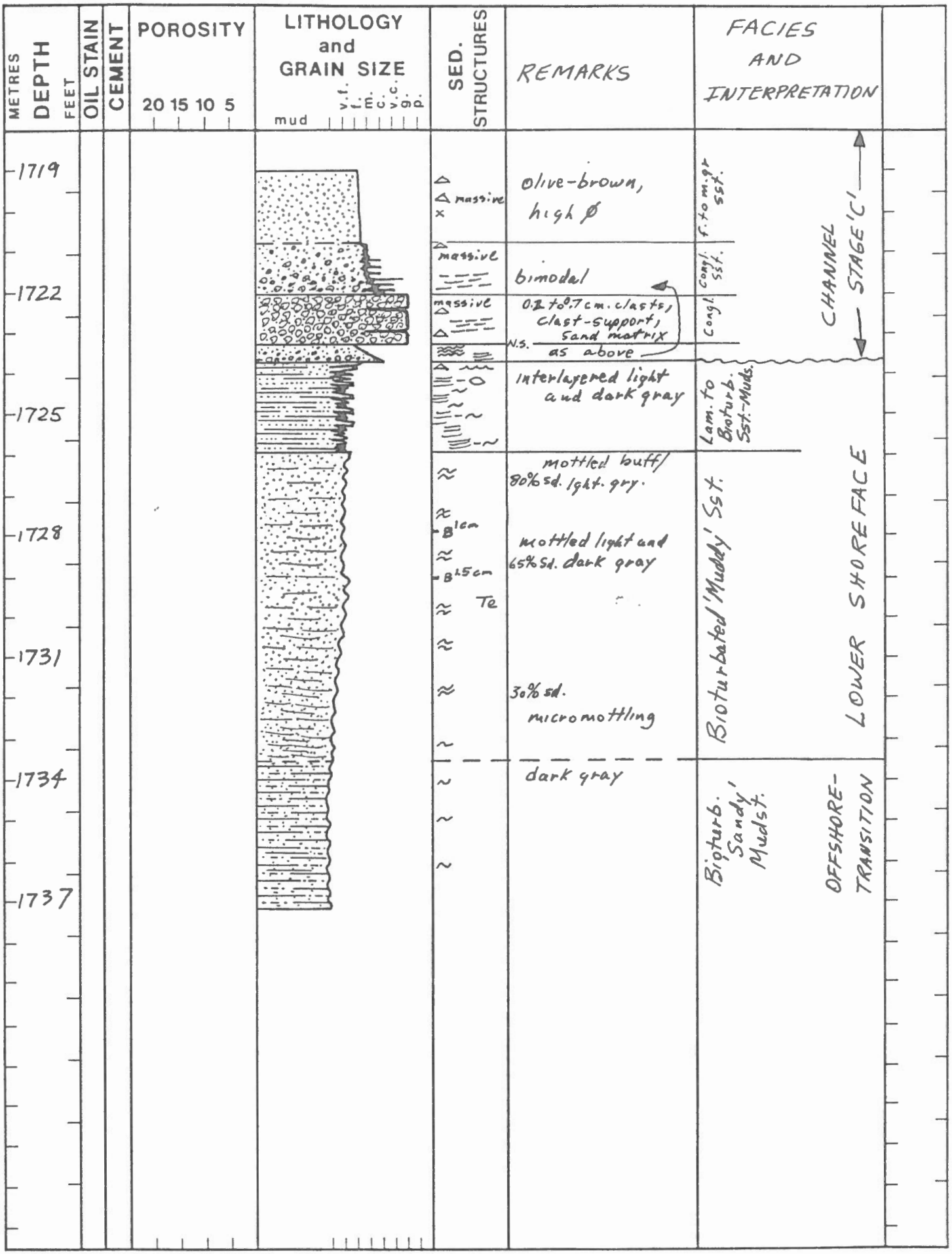
WELL NAME Westcoast et al. Crystal

LOCATION 4-7-46-3W5 (Continued) CORE INTERVAL 1735-1753



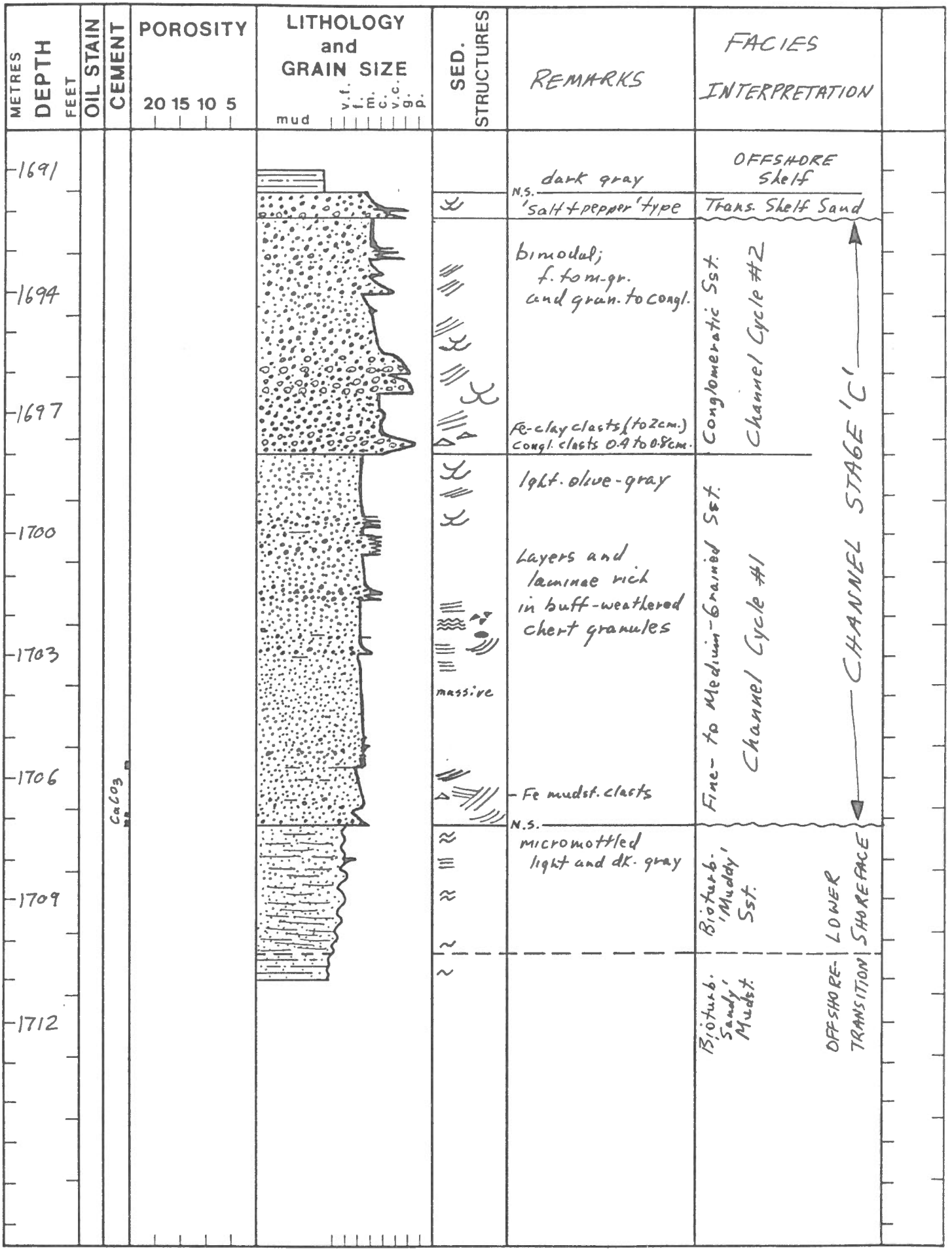
WELL NAME Bluesky et al Winfield (8cm diameter; partially slabbed)

LOCATION 8-7-46-3W5 CORE INTERVAL 1719-1737 (Rec 18.2)



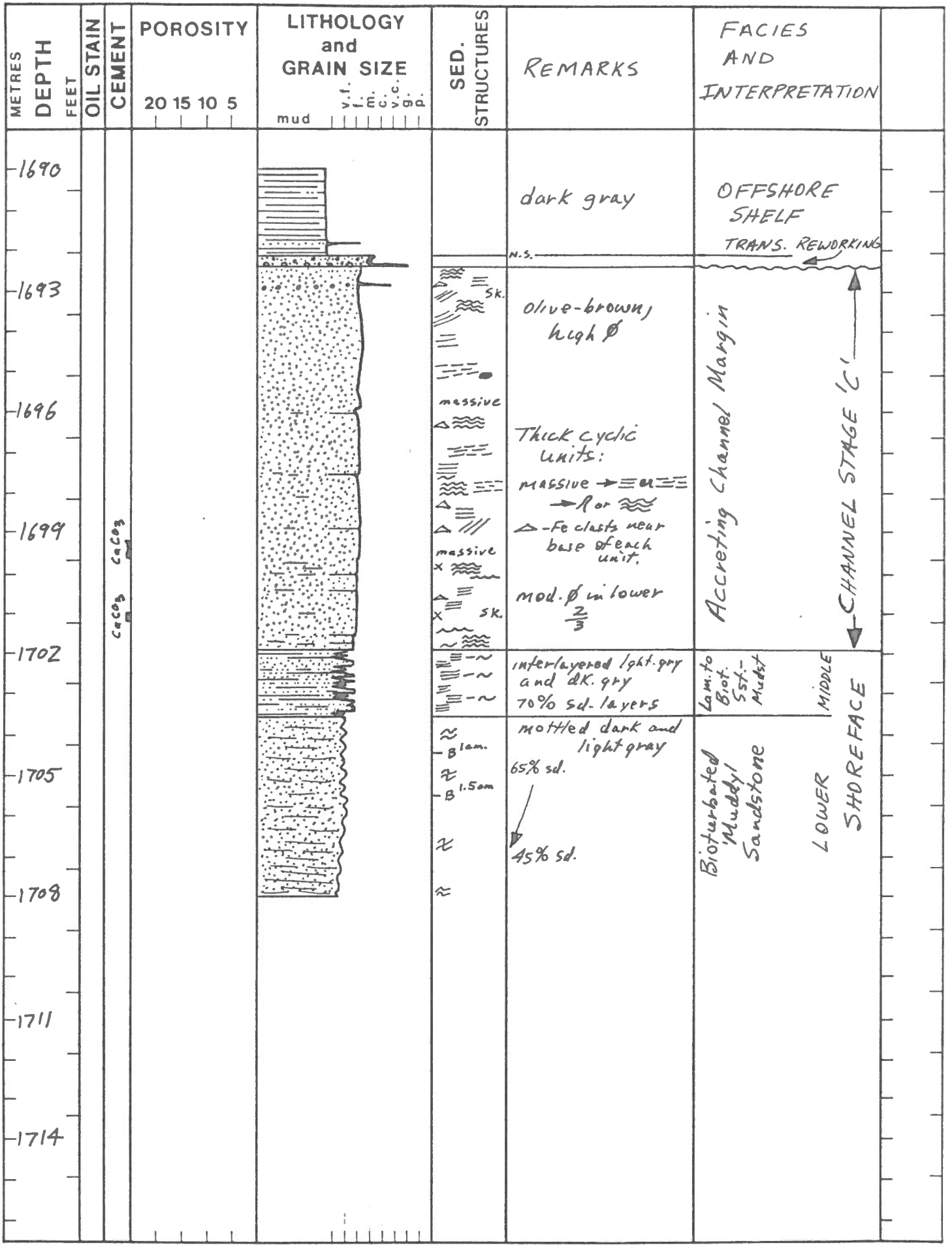
WELL NAME Dilezky et al Crystal (8cm diameter; partially slabbed)

LOCATION 14-7-46-3W5 CORE INTERVAL 1691-1696 (Rec 5m) 1696-1711 (Rec 15m)



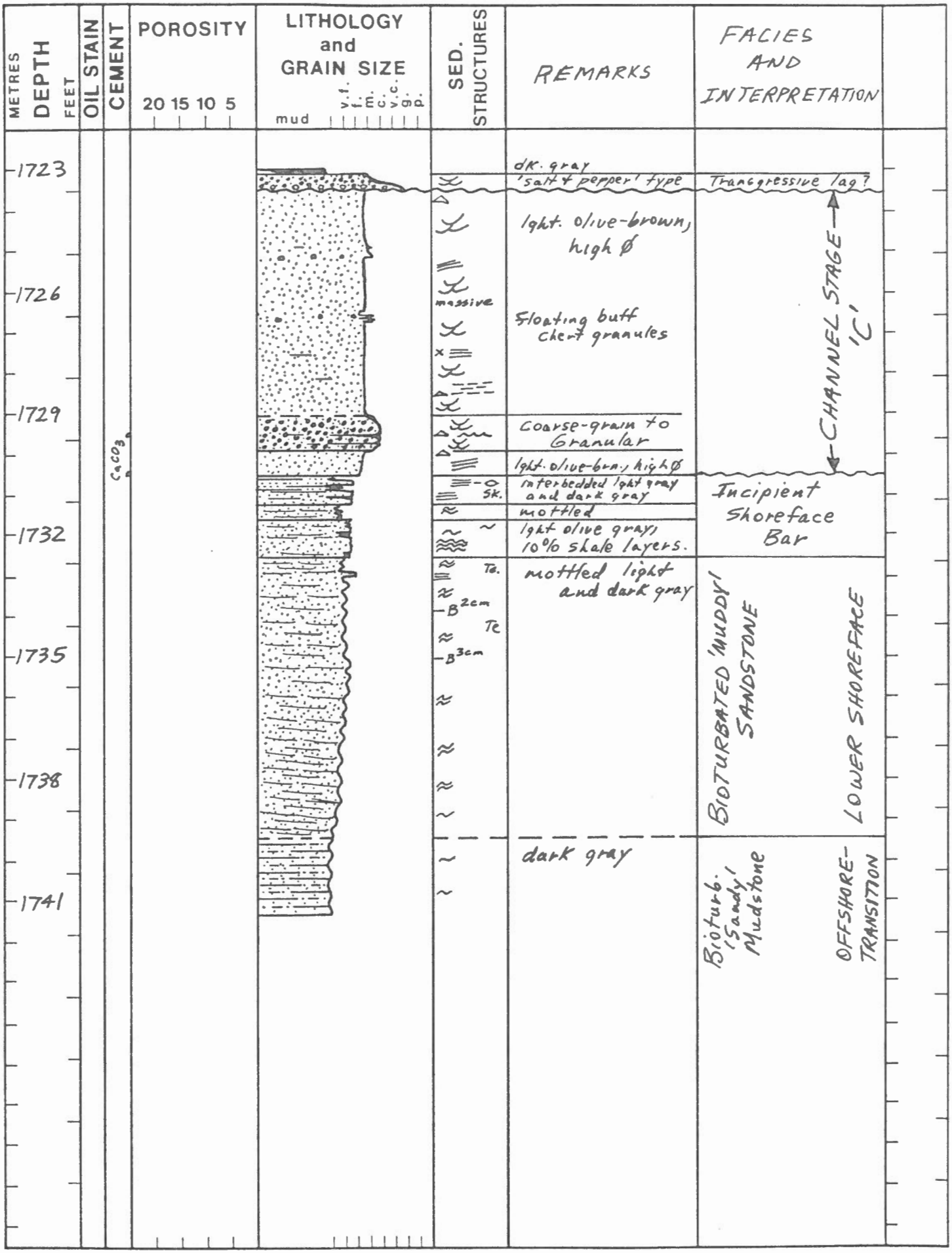
WELL NAME Westcoast et al Crystal (9cm diameter)

LOCATION 16-7-46-3W5 CORE INTERVAL 1690-1708 (Rec 18m)



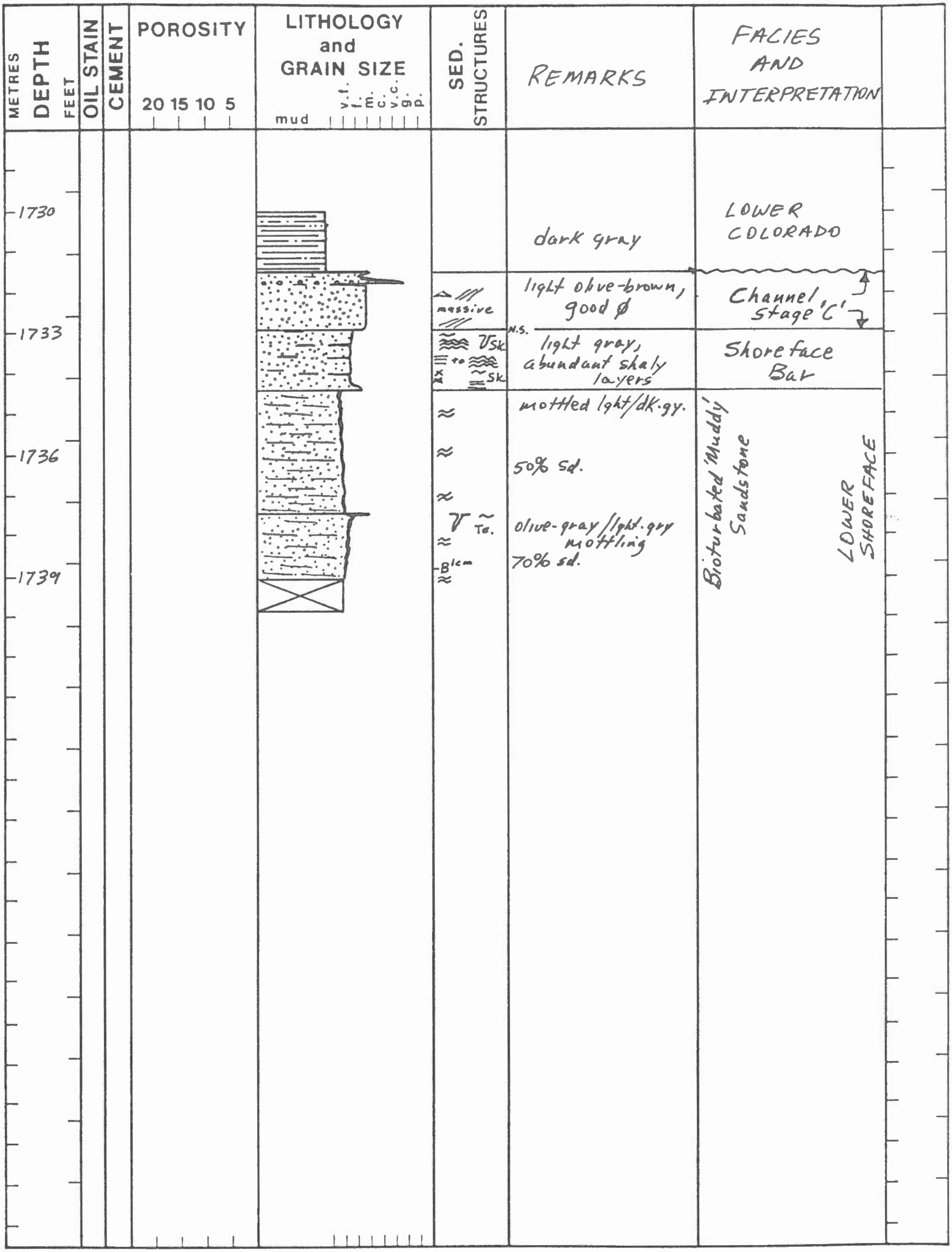
WELL NAME Westcoast Crystal (10cm diameter; unslabbed)

LOCATION 6-17-46-3W5 CORE INTERVAL 1723-1741.25 (Rec 18.25)



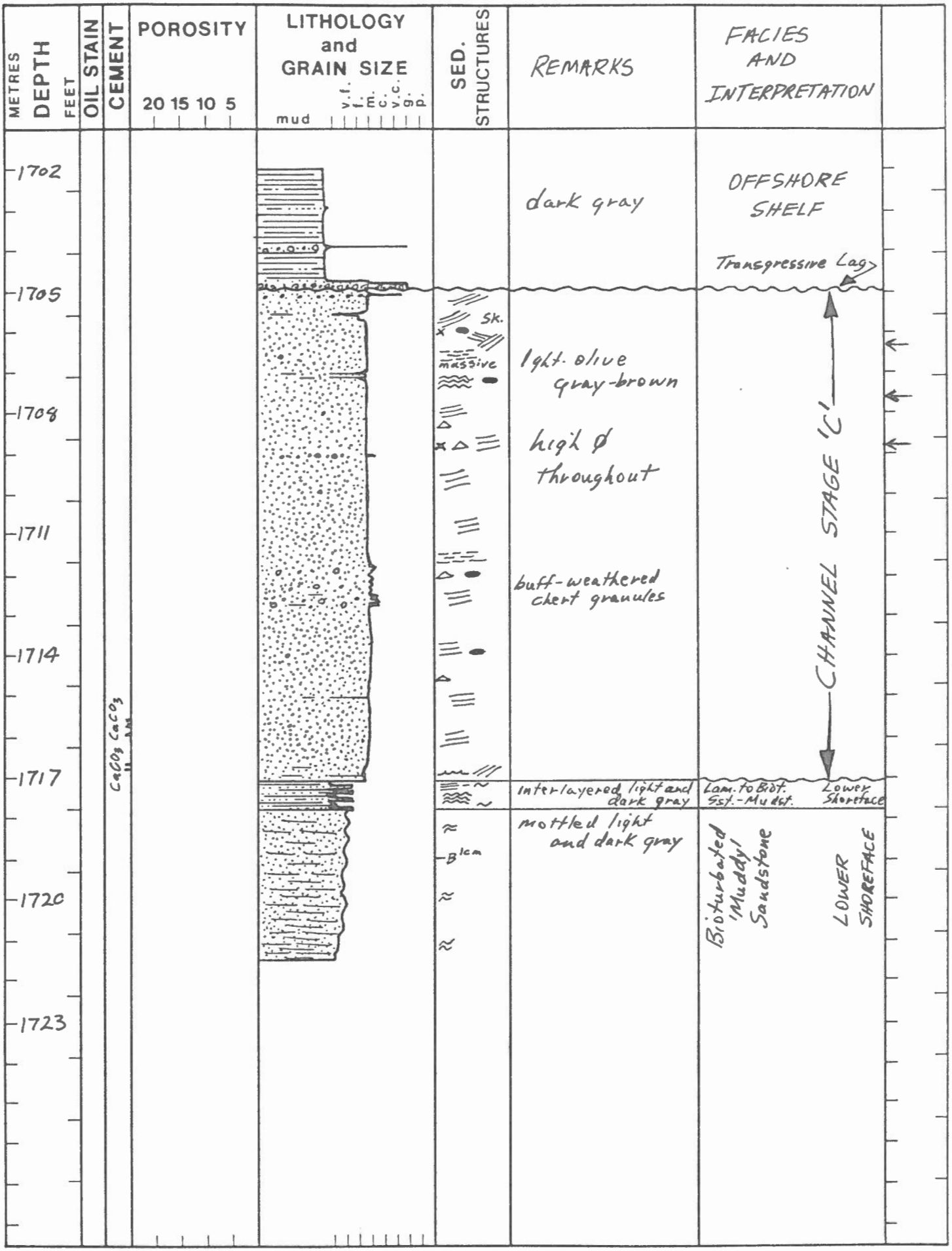
WELL NAME [illegible] Crystal 1212 [illegible]

LOCATION 16-17-46-3W5 **CORE INTERVAL** 1730-1739.8 (Rec 9.1m)



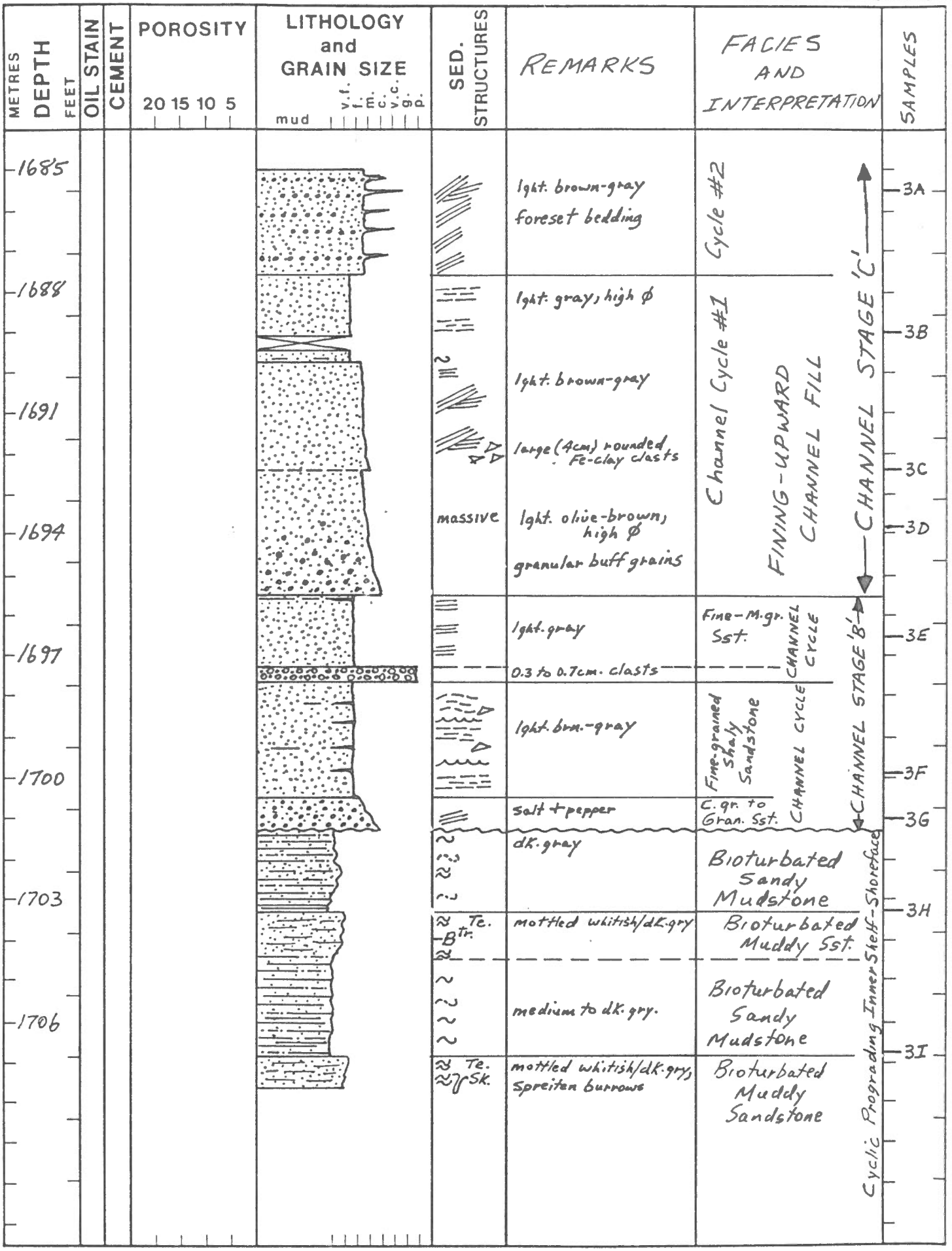
WELL NAME Westcoast et al Crystal (10cm diameter; unslabbed)

LOCATION 2-18-46-3W5 CORE INTERVAL 1702-1705 (Rec 3.0m) 1705-1721.5 (Rec 16.5m)



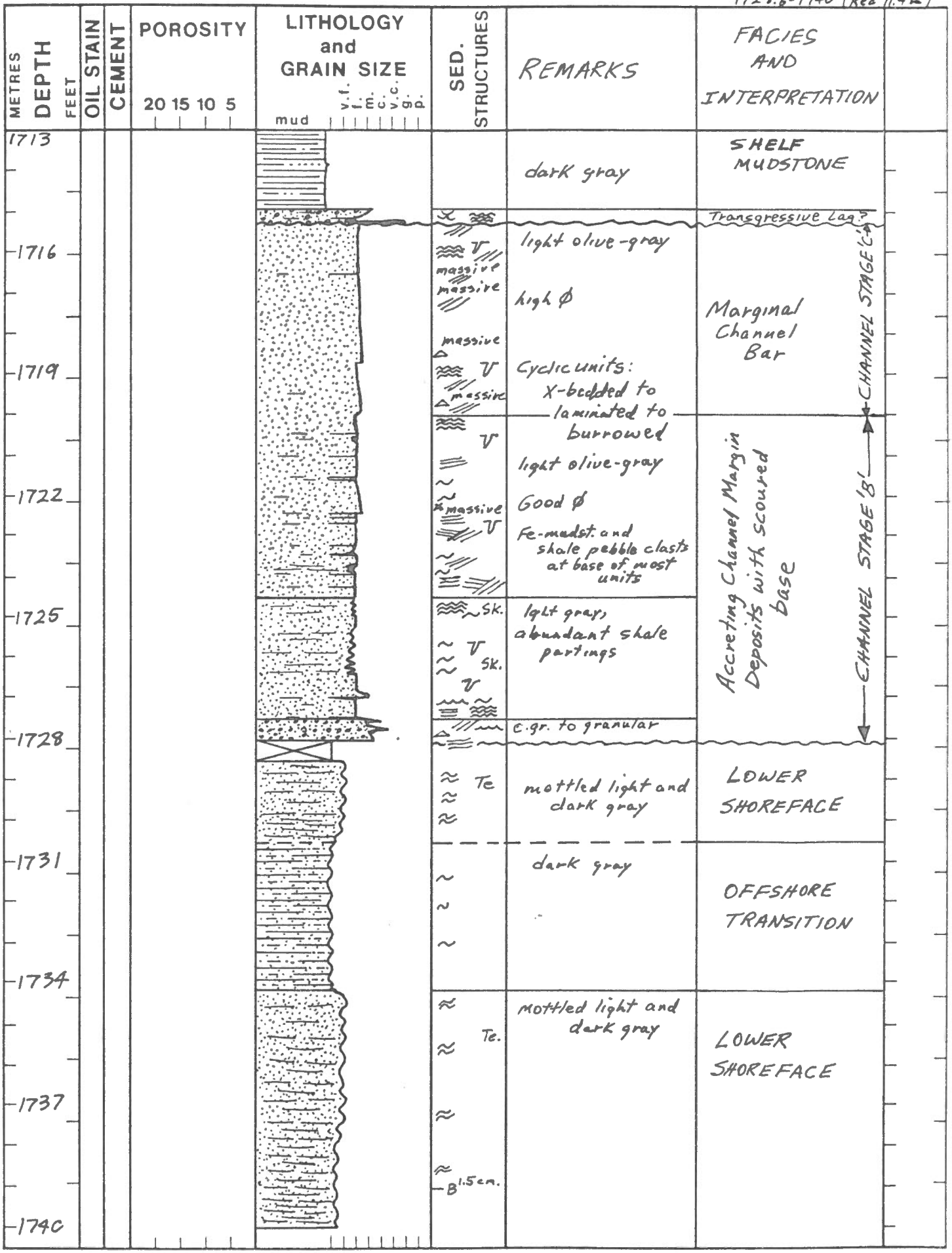
WELL NAME West Coast et al. Crystal (ucm.) unstudied, many core intervals missing)

LOCATION 3-18-46-3w5 CORE INTERVAL 1685-1689.5 (Rec. 4.15)
~~1689.5-1707.5 (Rec. 16.23~~



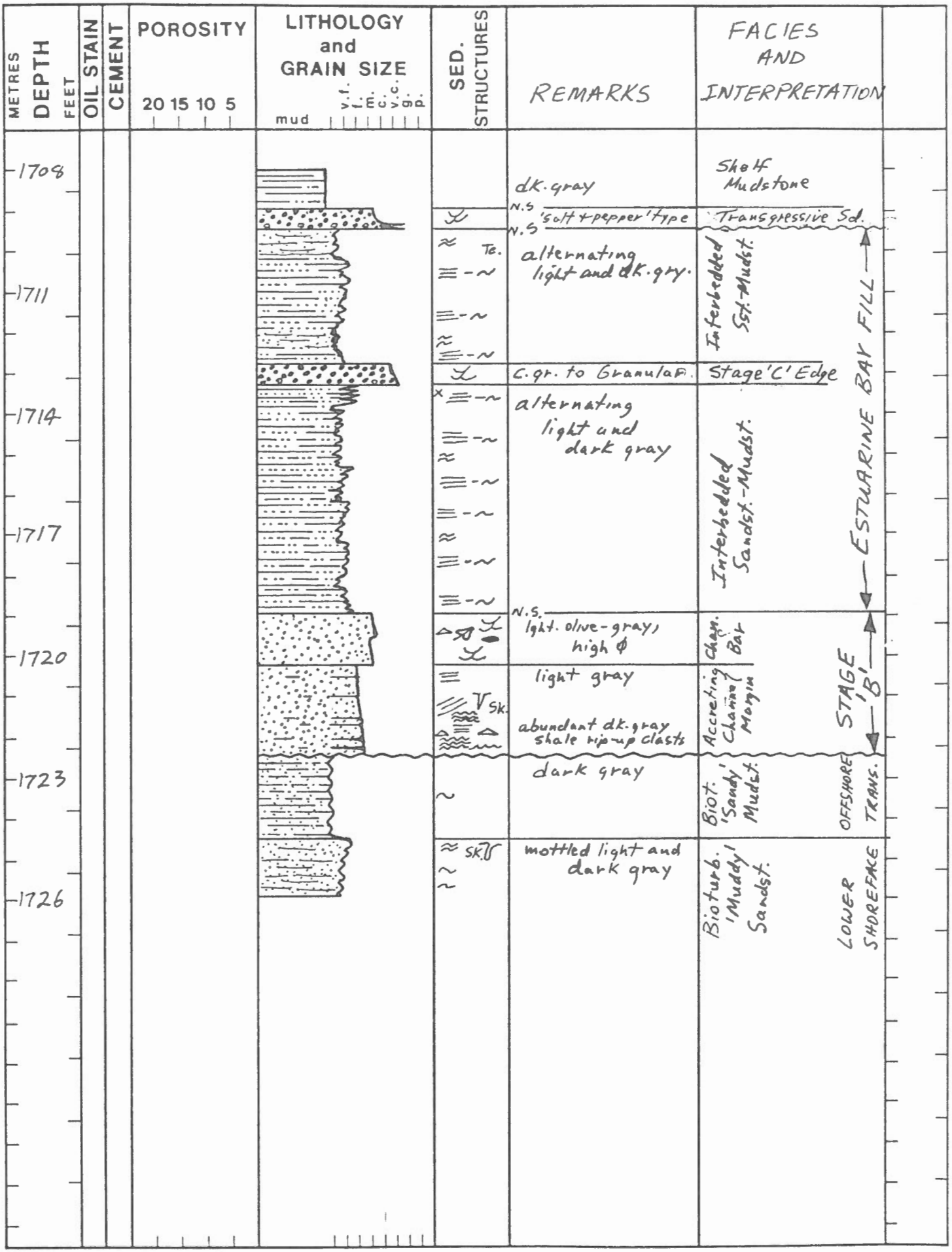
WELL NAME Westcoast et al Crystal (10cm diameter, partially slabbed)

LOCATION 10-18-46-3W5 CORE INTERVAL 1707-1725 (Rec 18m) 1725-1728.6 (Rec 3.1m) 1728.6-1740 (Rec 11.4m)



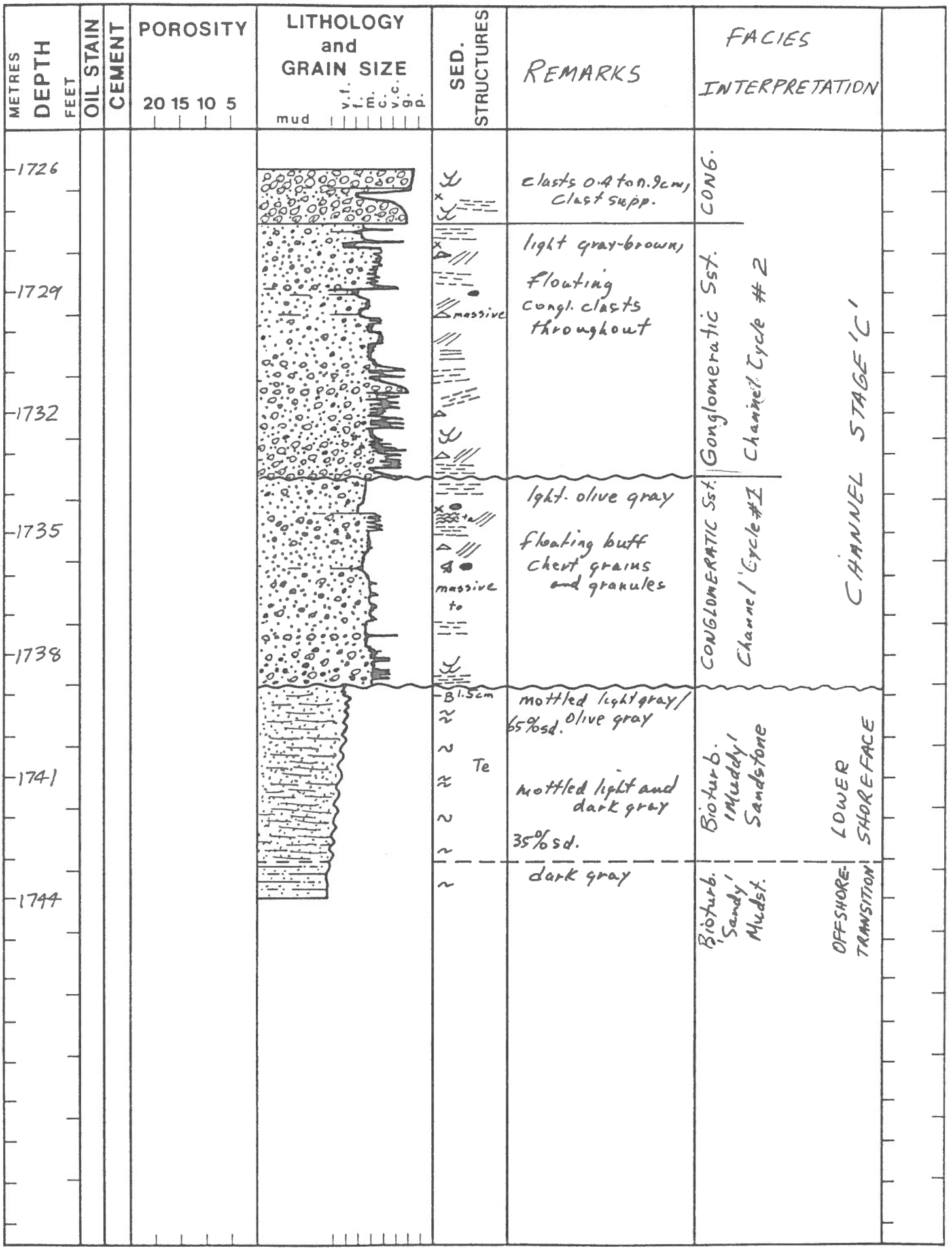
WELL NAME West Coast et al Crystal (10 cm diameter; unslabbed)

LOCATION 12-18-46-3W5 CORE INTERVAL 1708-1725.8 (Rec 17.6



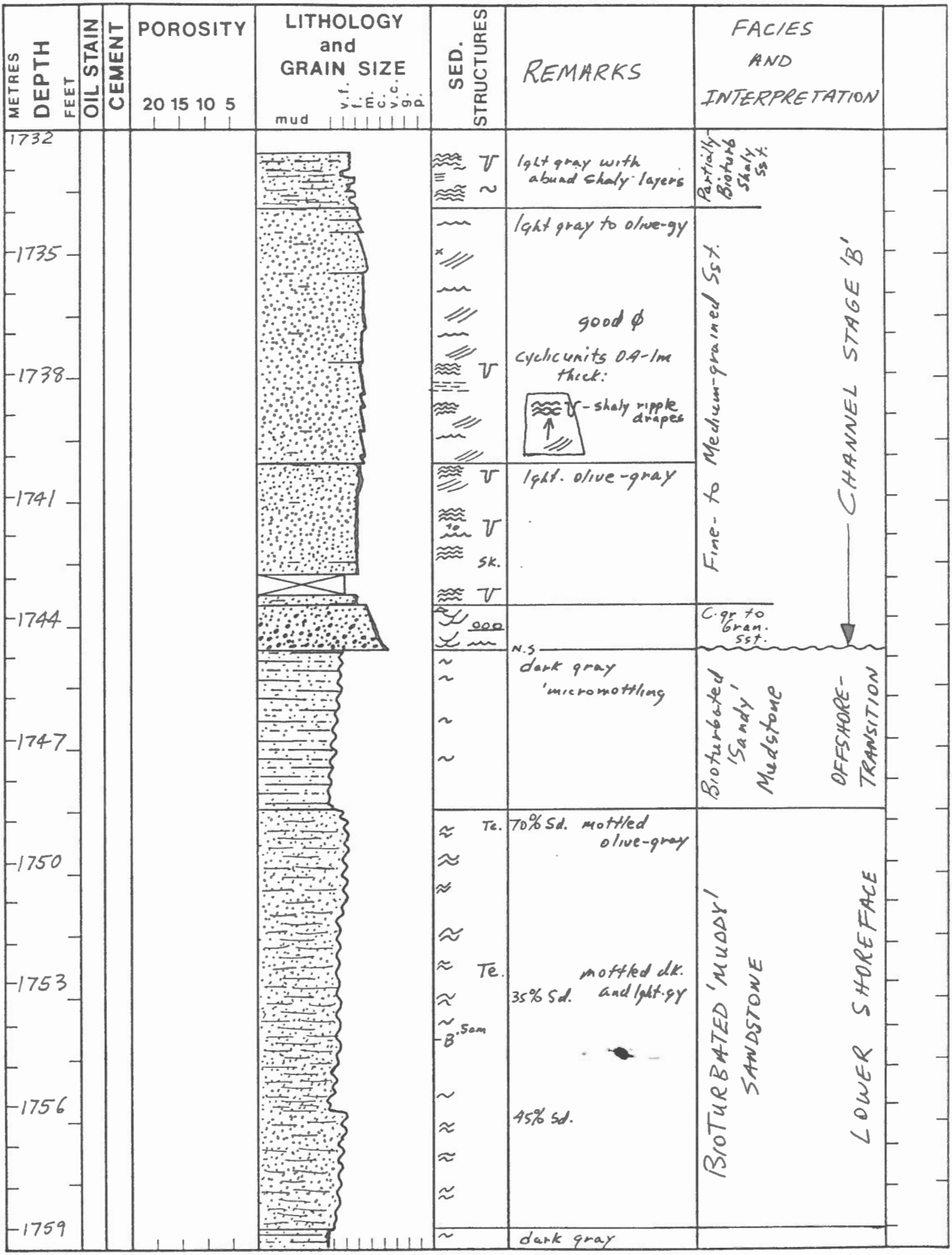
WELL NAME Westcoast et al Crystal (10cm diameter; partially slabbed)

LOCATION 16-18-46-3W5 CORE INTERVAL 1726-1744 (Rec 18m)



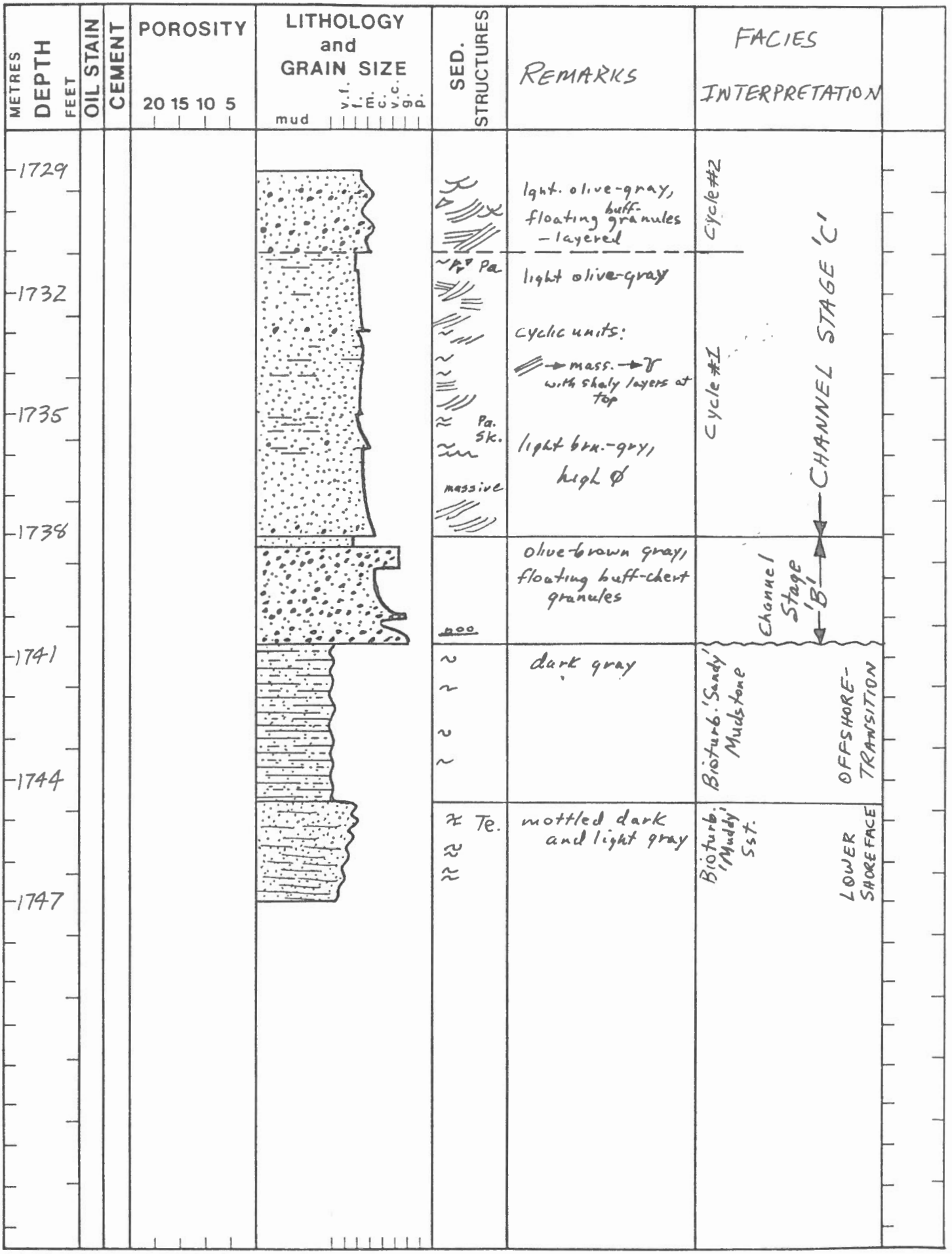
WELL NAME Westcoast et al Crystal (8cm diameter; partially slabbed)

LOCATION 2-19-46-3w5 CORE INTERVAL 1732.6-1743.4 (Rec 10.3m)
1743.4-1761.4 (Rec 17.3m)



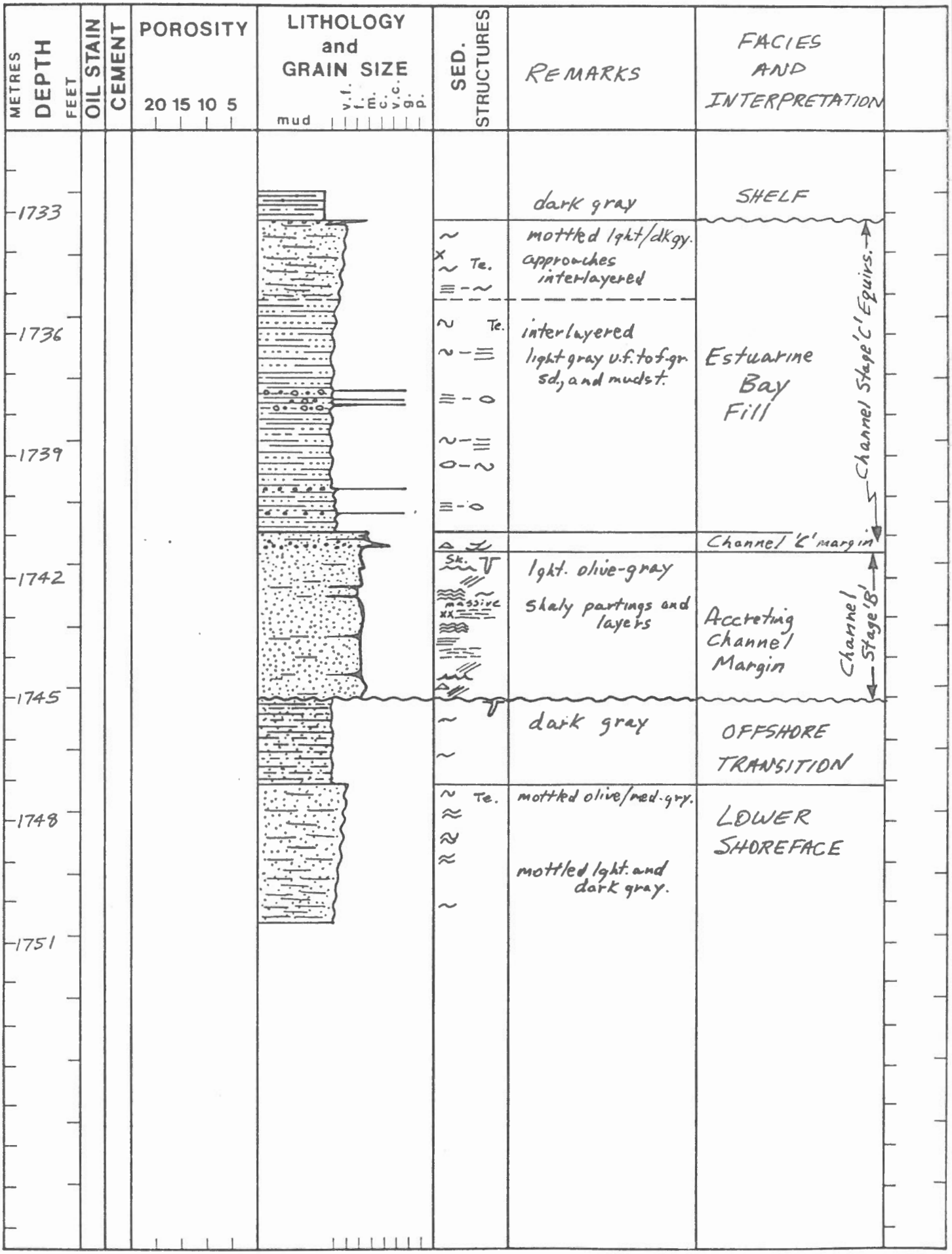
WELL NAME WESTCOAST UNL CRYSTAL

LOCATION 8-19-46-3W5 CORE INTERVAL 1729-1747



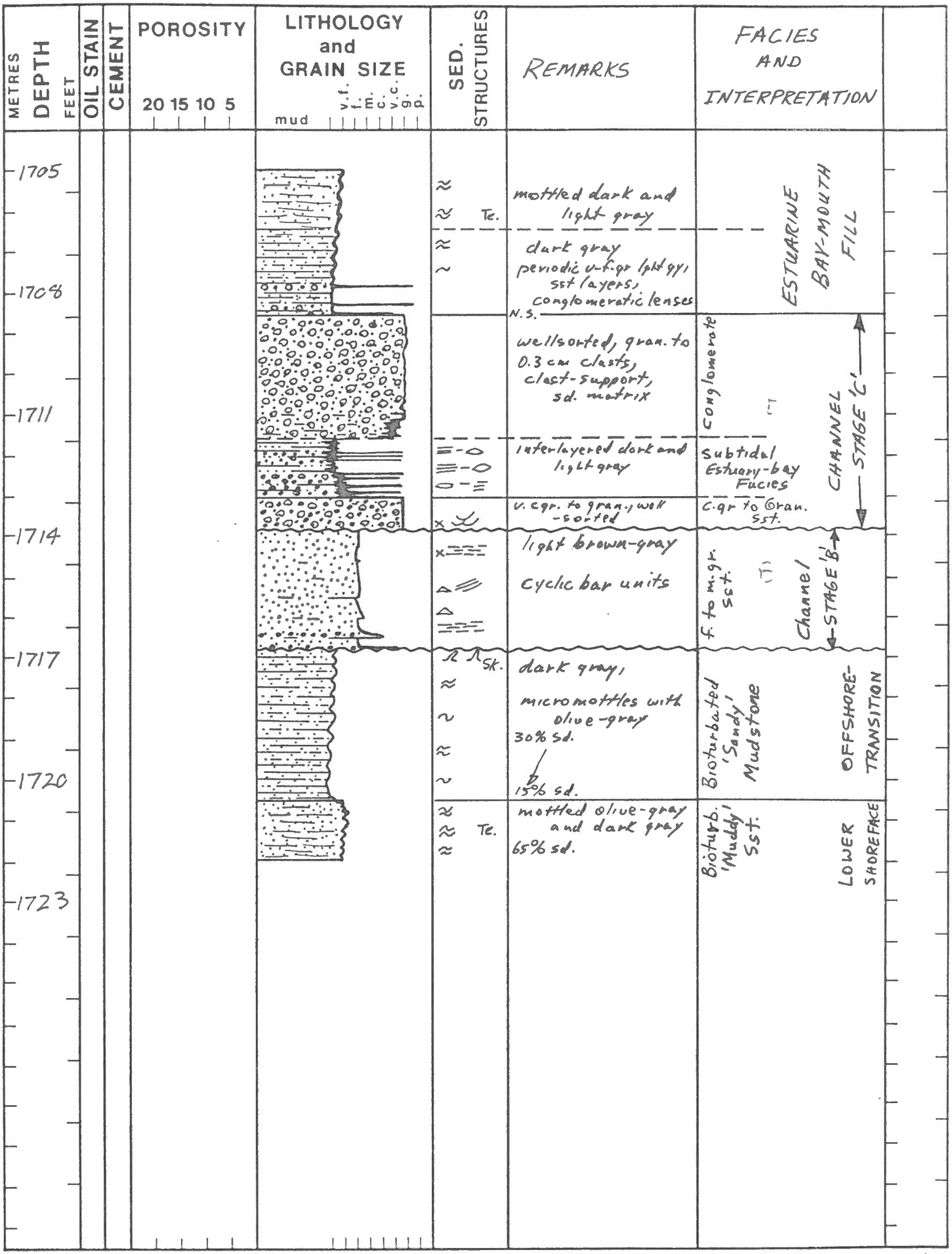
WELL NAME Westcoast et al Crystal (4" diameter; partially slabbed)

LOCATION 12-19-46-3W5 CORE INTERVAL 1732.5-1750.5



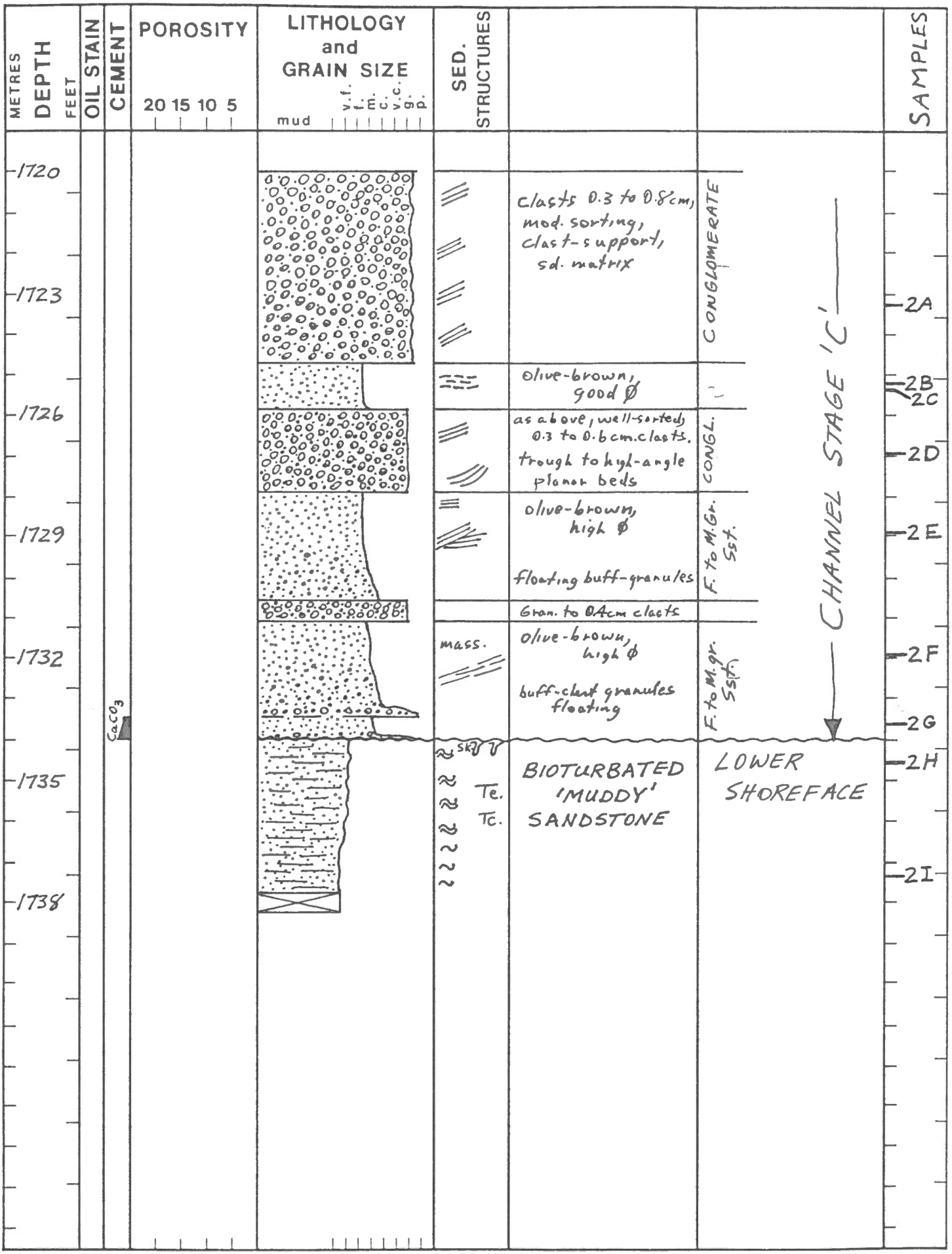
WELL NAME West Coast et al Crystal (4 diameter, unslabbed)

LOCATION 14-19-46-3W5 CORE INTERVAL 1705-1721.9 (Rec 16.9m)



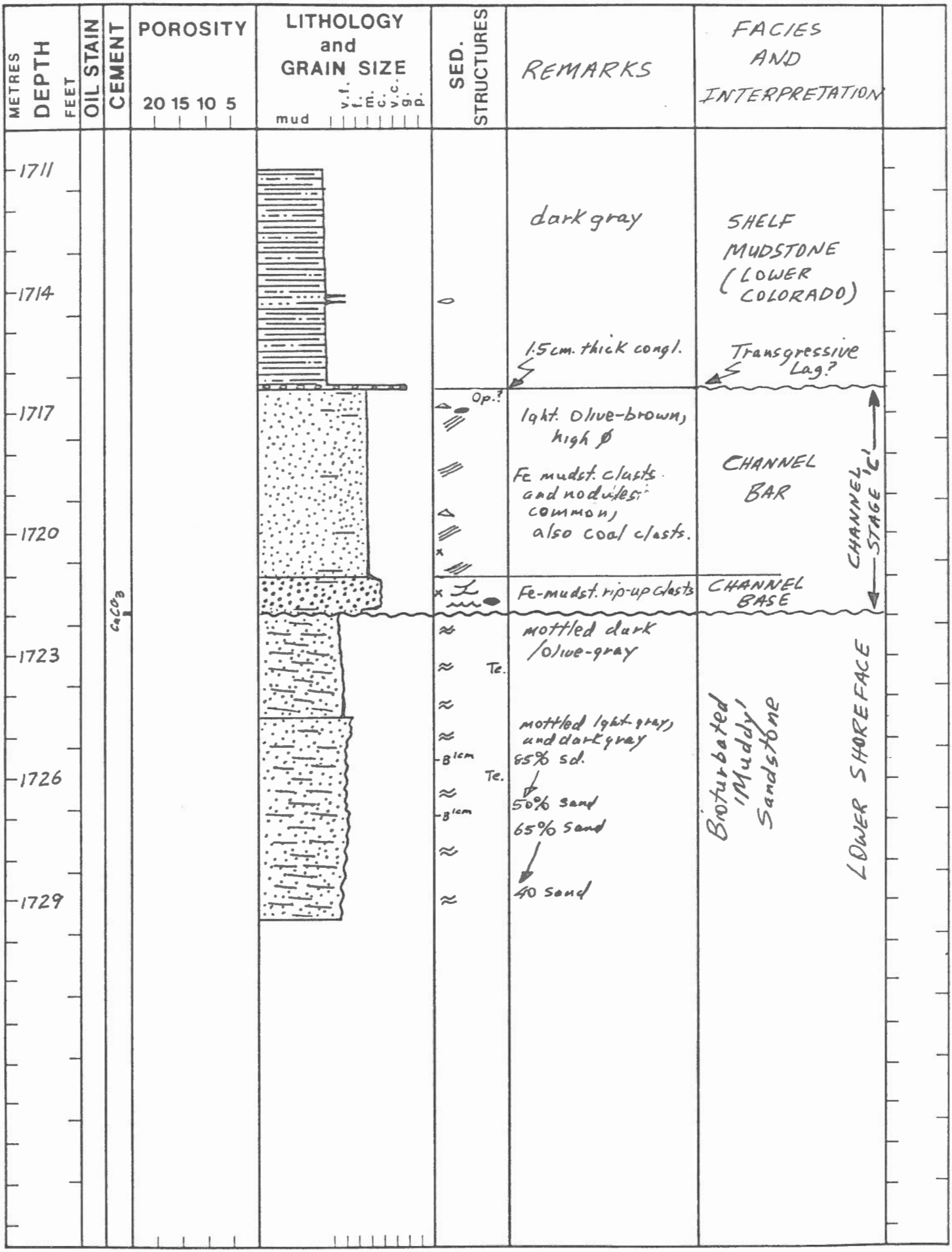
WELL NAME Bumper et. al Crystal (10cm diameter, unslabbed)

LOCATION 6-20-46-3 w5 CORE INTERVAL 1720-1738.25 (Rec. 1775)



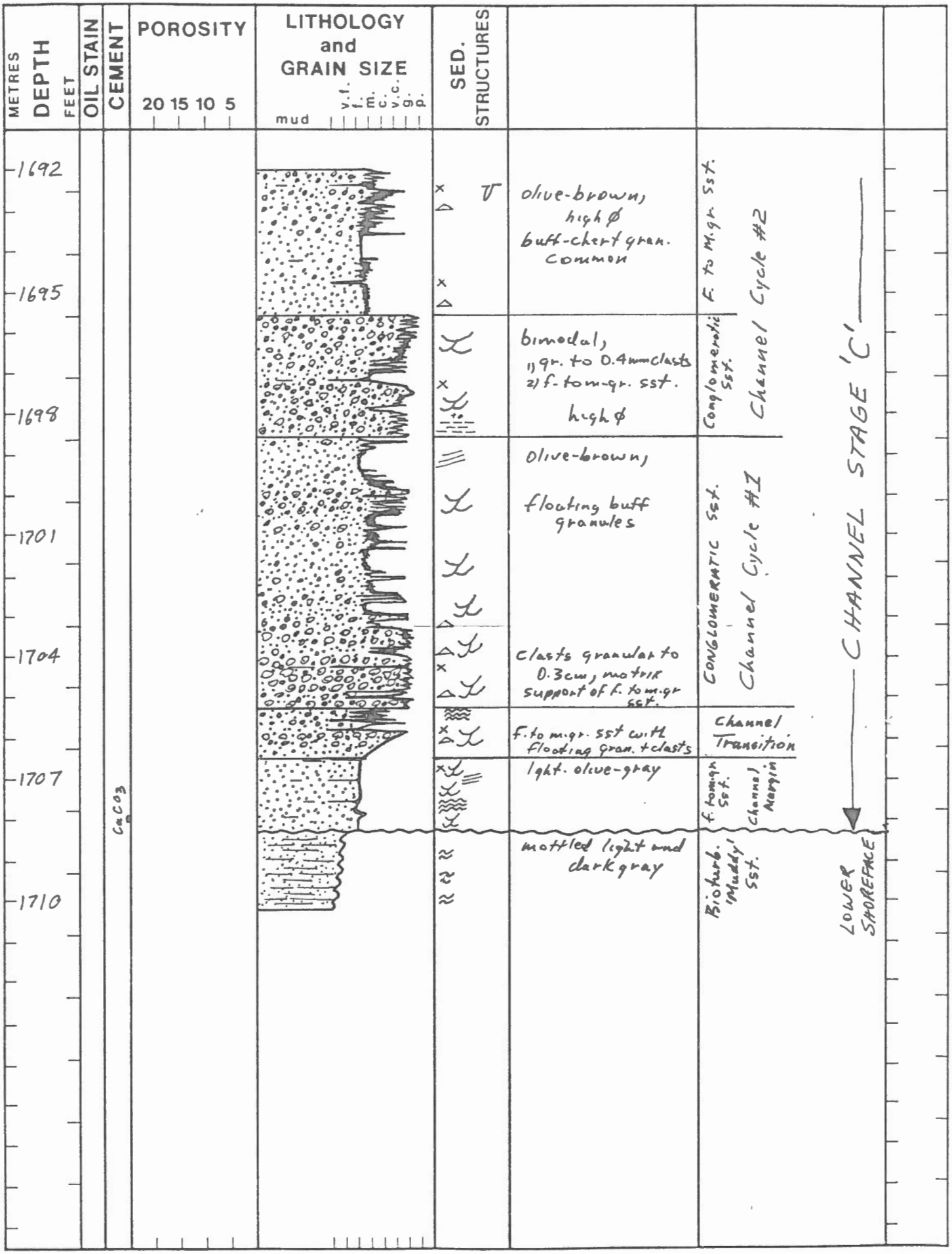
WELL NAME Bumper Crystal (4" diameter; partially slabbed)

LOCATION 8-20-46-3W5 CORE INTERVAL 1711-1729.5 (Rec 18.5m)



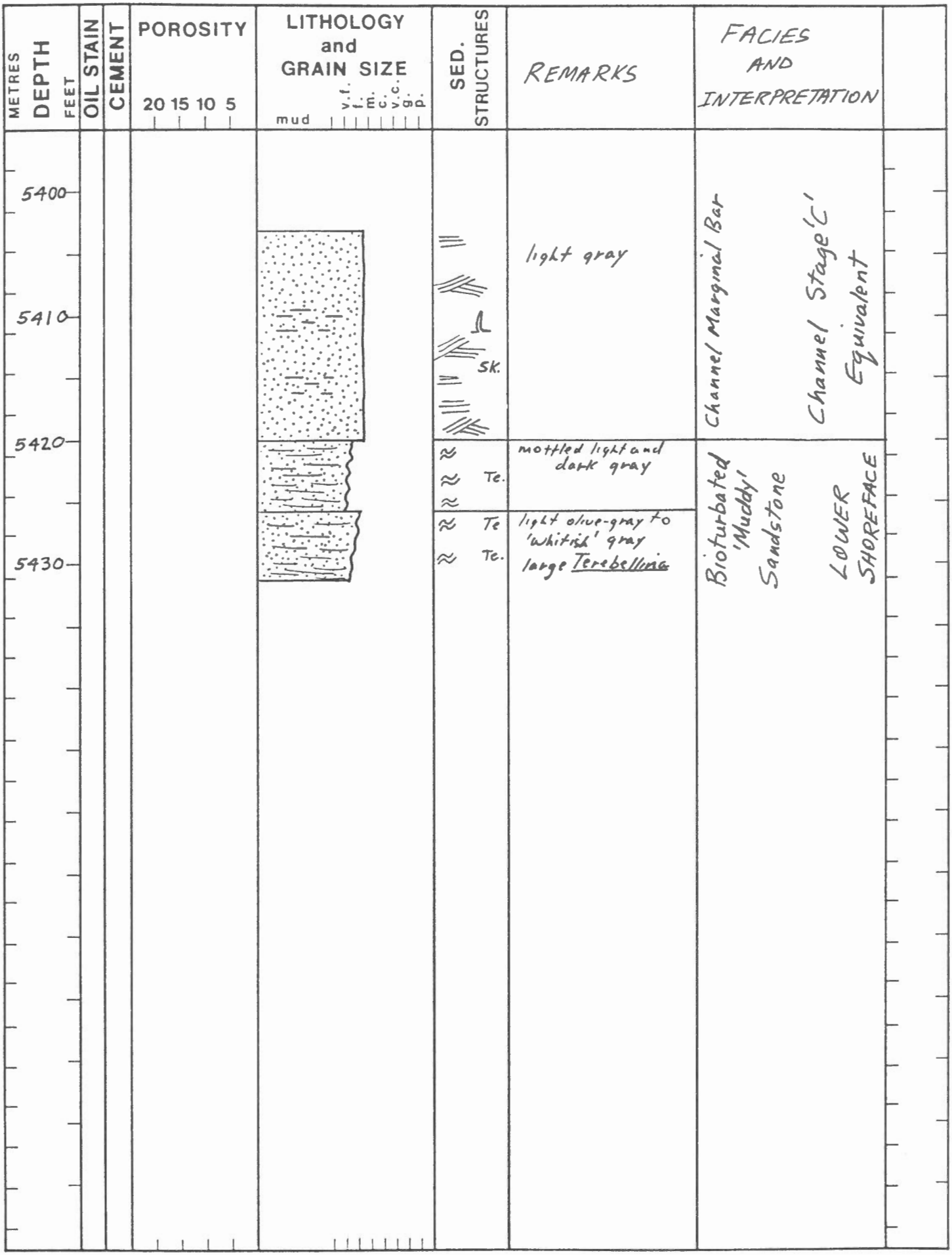
WELL NAME Westcoast et al Crystal (10cm diameter; partially slabbed)

LOCATION 14-20-46-3W5 CORE INTERVAL 1692-1710.2 (Rec 17.6m)



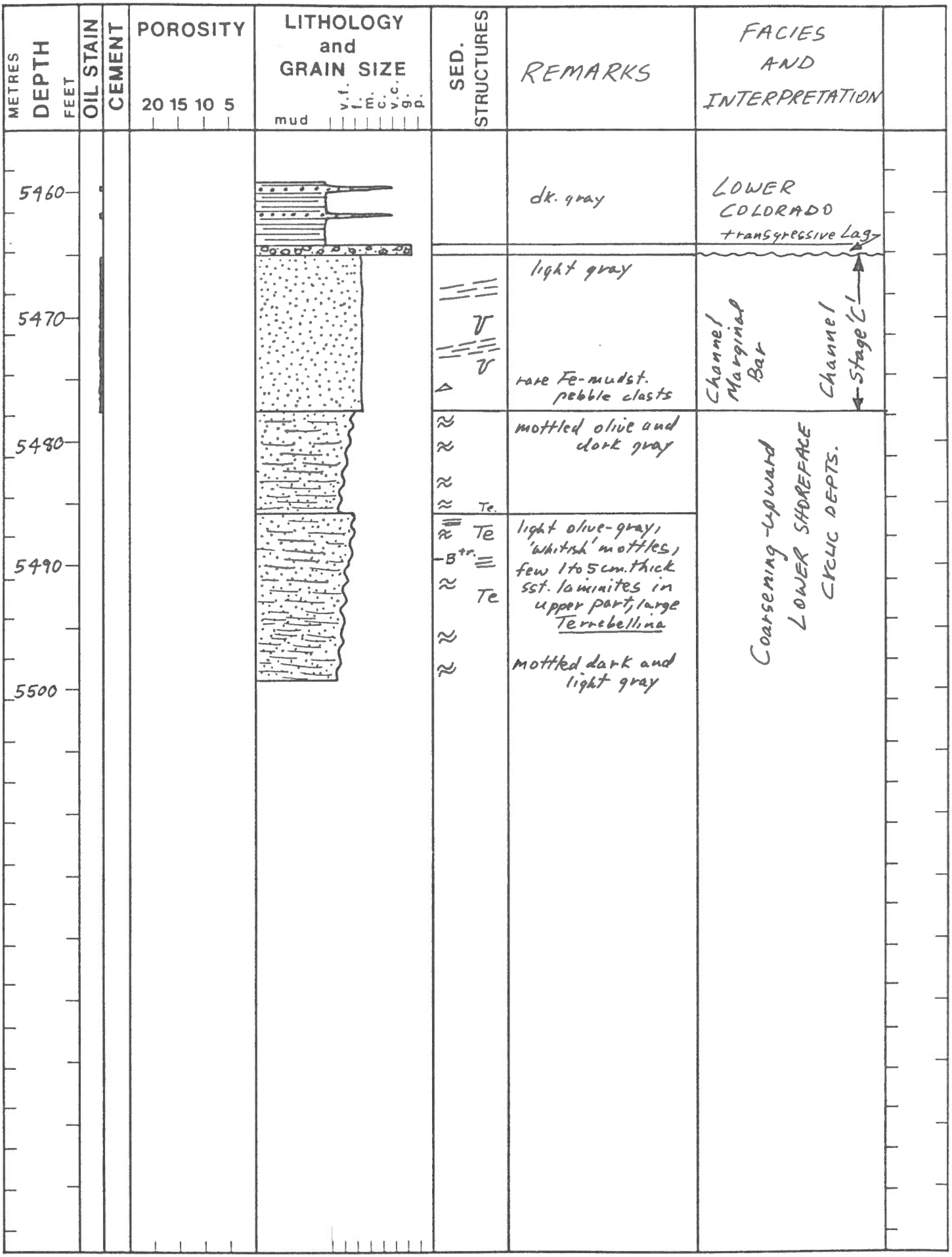
WELL NAME Focus Pembina (10 cm diameter; unslabbed)

LOCATION 11-27-46-3W5 CORE INTERVAL 5403-5432 (Rec 28.5)



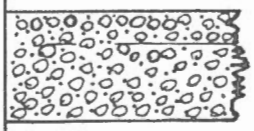
WELL NAME _____ (1cm diameter, unslabbed)

LOCATION 10-28-46-3 W5 CORE INTERVAL 5459-5499 ft.



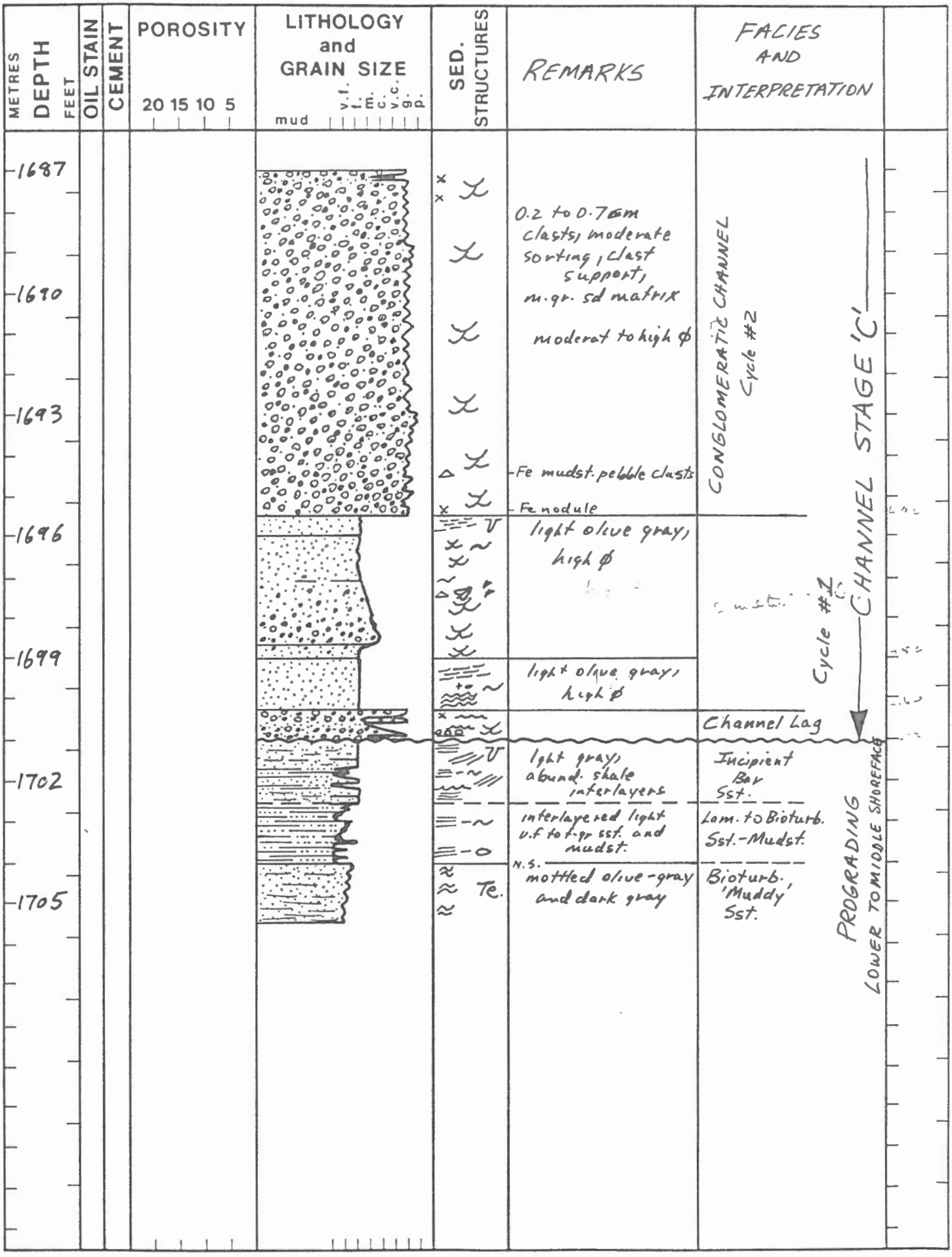
WELL NAME V.I.L. Westcoast 41 Crystal (5½ diameter; unslabbed,

LOCATION 6-29-46-3w5 CORE INTERVAL 1670-1671.5 (Rec 1.75m

METRES DEPTH FEET	OIL STAIN	CEMENT	POROSITY 20 15 10 5	LITHOLOGY and GRAIN SIZE mud v.f. f. m. c. v.c. g. p.	SED. STRUCTURES	REMARKS	FACIES AND INTERPRETATION	
1670						clasts 0.3 to 0.8cm, clast support, m.gr sst. matrix	CONGLOMERATE — CHANNEL STAGE 'C'	
1673								

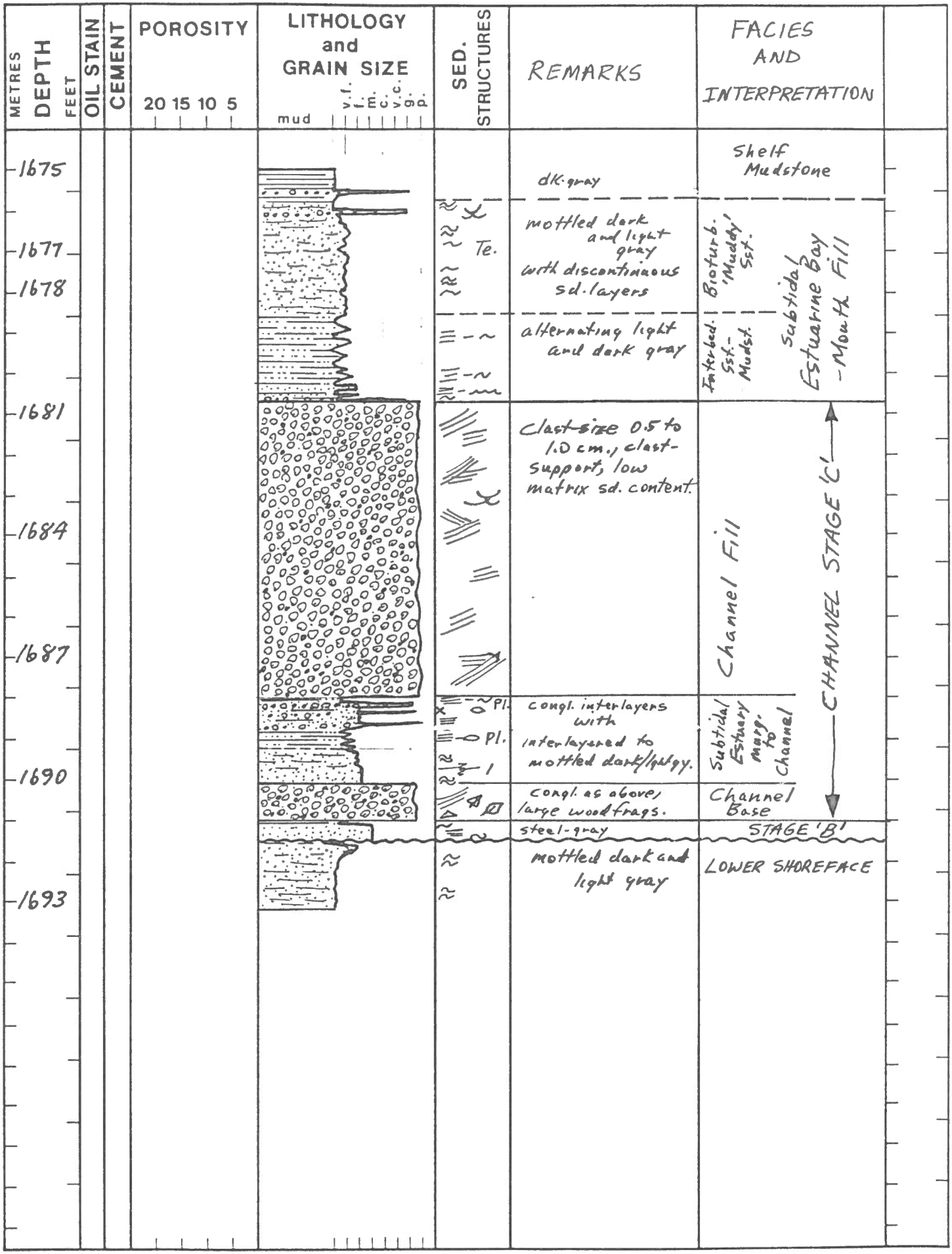
WELL NAME Westcoast et al Crystal (10cm diameter; partially slabbed)

LOCATION 2-30-46-3W5 CORE INTERVAL 1687-1705.4 (Rec 18.4m)



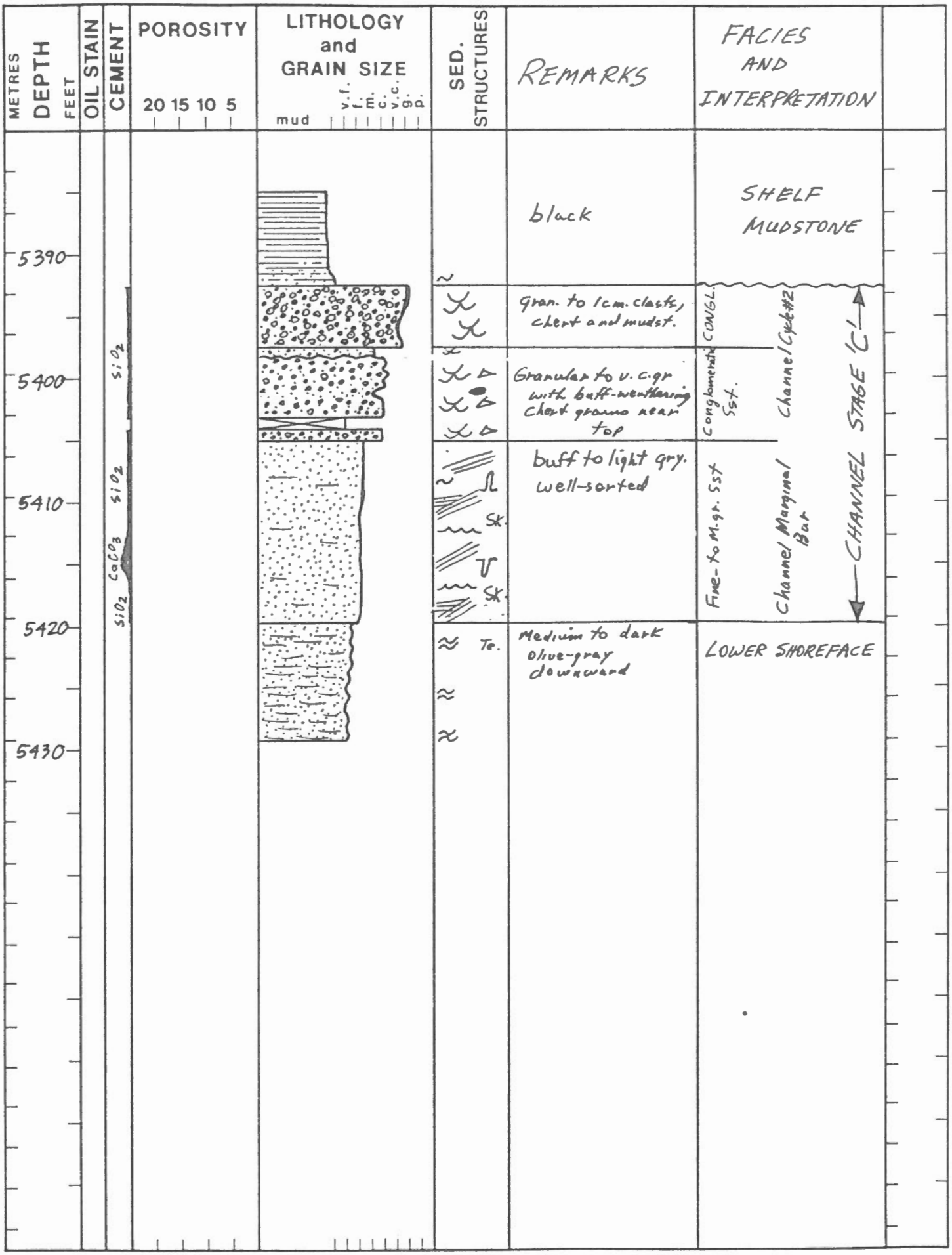
WELL NAME UL Wes/Coast 47 Crystal (6cm. diameter; 4 slabbed)

LOCATION 16-30-46-3w5 CORE INTERVAL 1675 - 1693.15



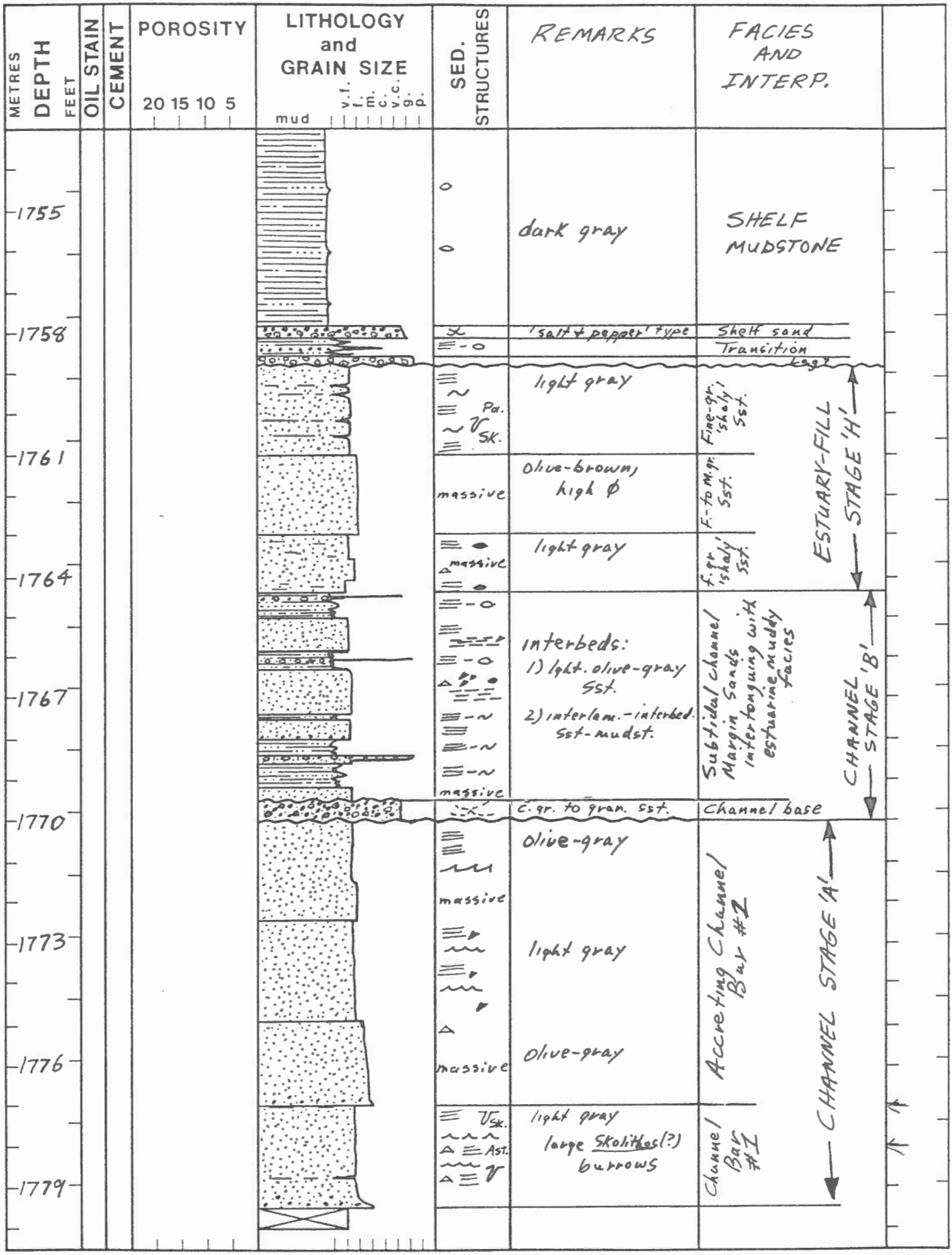
WELL NAME Lego Penn. Wintield (1cm diameter; unslabbed)

LOCATION 2-32-46-3W5 CORE INTERVAL 5385-5404 (Rec 18') 5404-5429 (Rec 20')



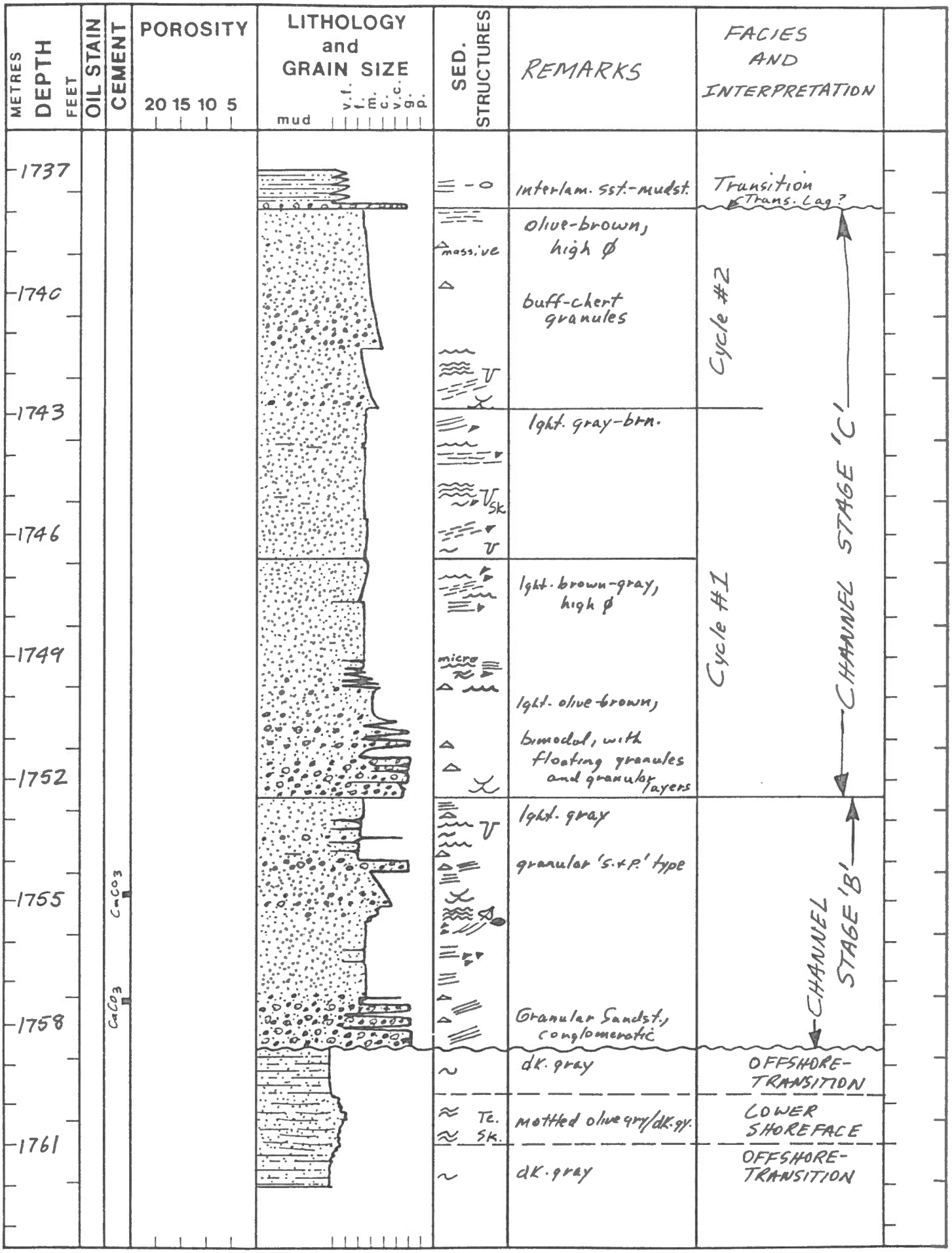
WELL NAME Petrocan Murphy Crystal

LOCATION 6-1-46-4W5 CORE INTERVAL 1752-1770 (Rec 18m) 1770-1779.75 (Rec 9.45m)



WELL NAME ARCTIC PETROLEUM CRYSTAL (10 cm diameter; unslabbed)

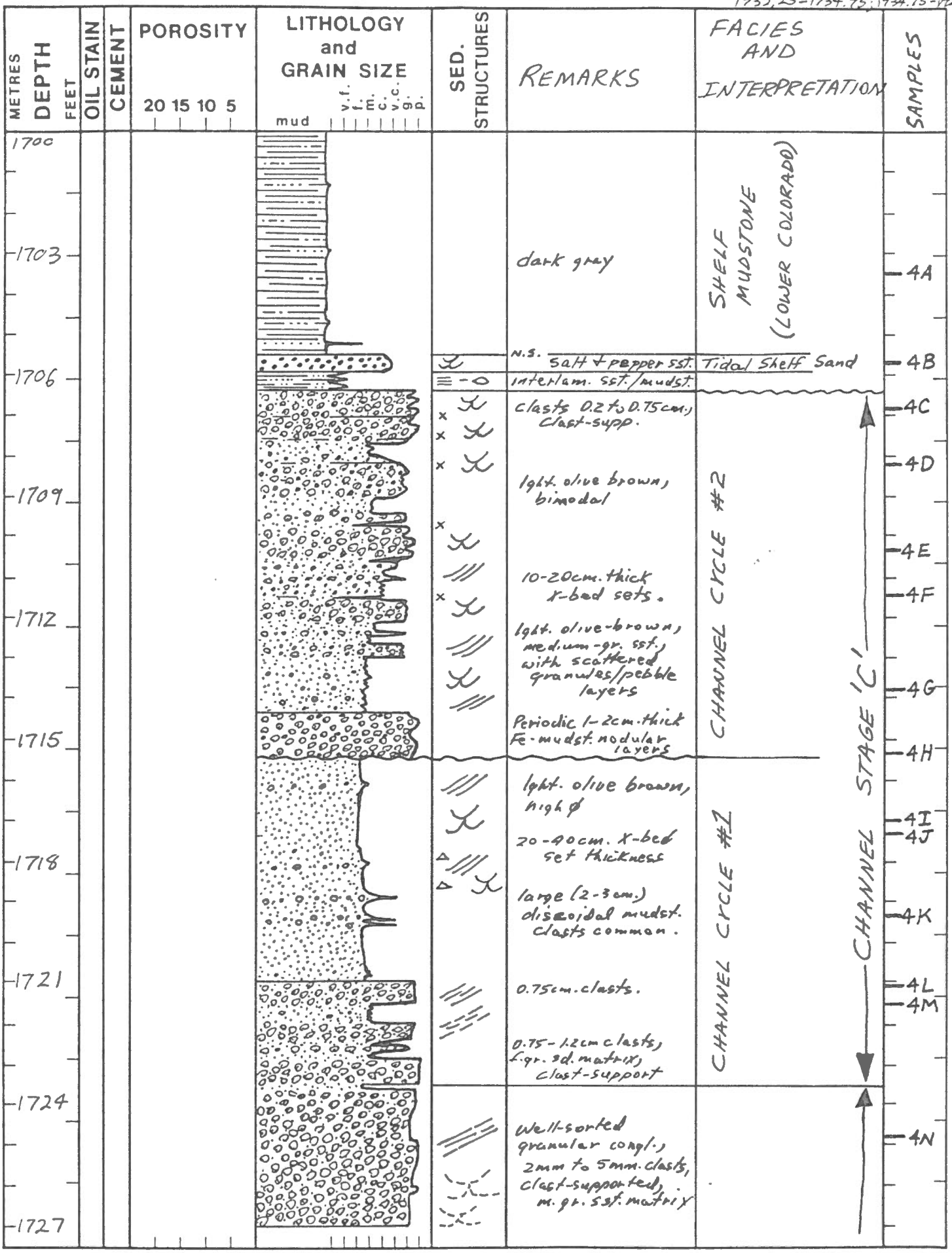
LOCATION 8-1-46-4W5 CORE INTERVAL 1737-1755 (Rec 18.2m) 1755-1762 (Rec 7.0m)



WELL NAME West Coast et al crystal (10cm diameter; unslabbed)

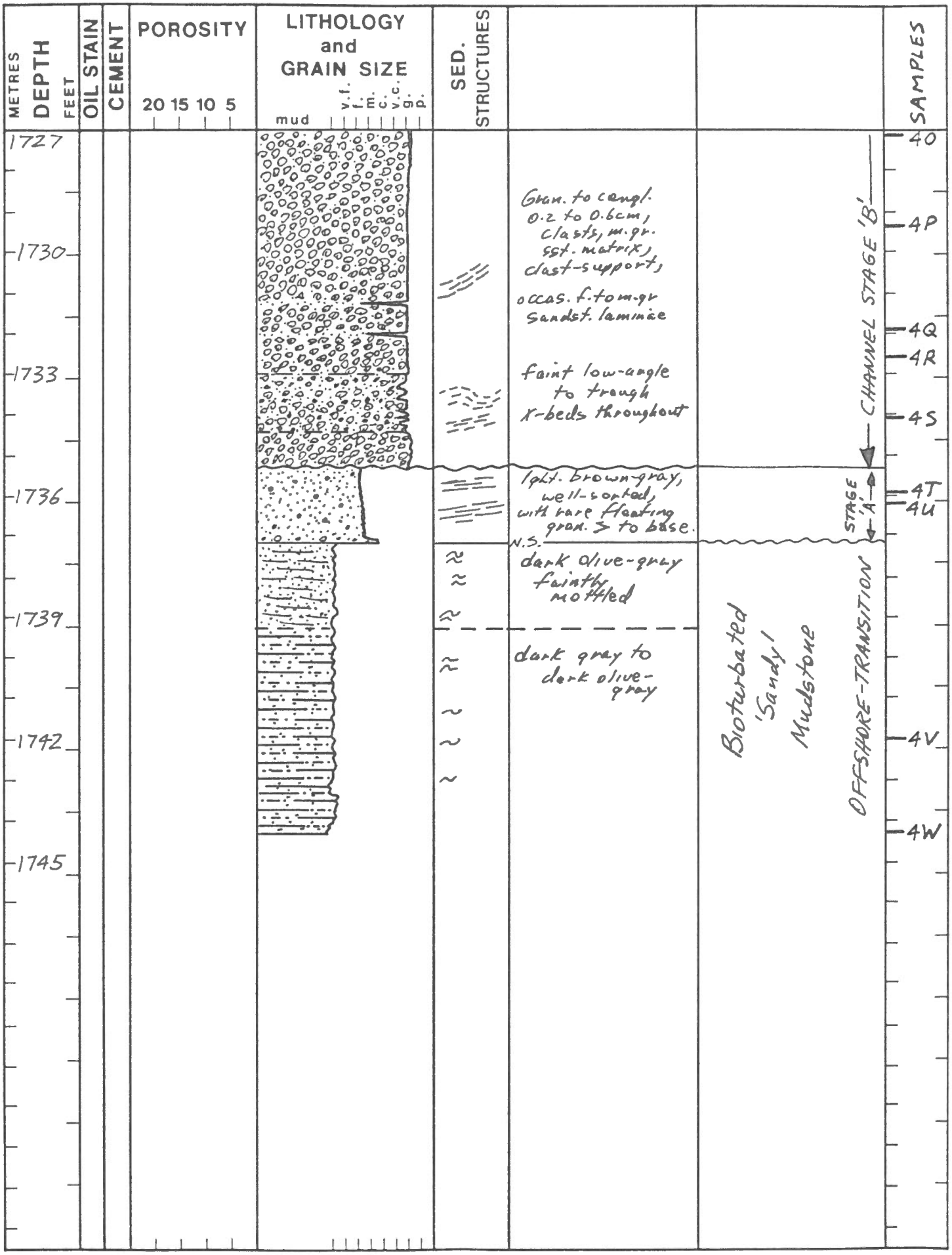
LOCATION 10-1-46-4w5

CORE INTERVAL 1700 - 1714.25 (Rec 14.25m)
1714.25 - 1732.25 (Rec 18m)
1732.25 - 1739.75; 1739.75 - TD



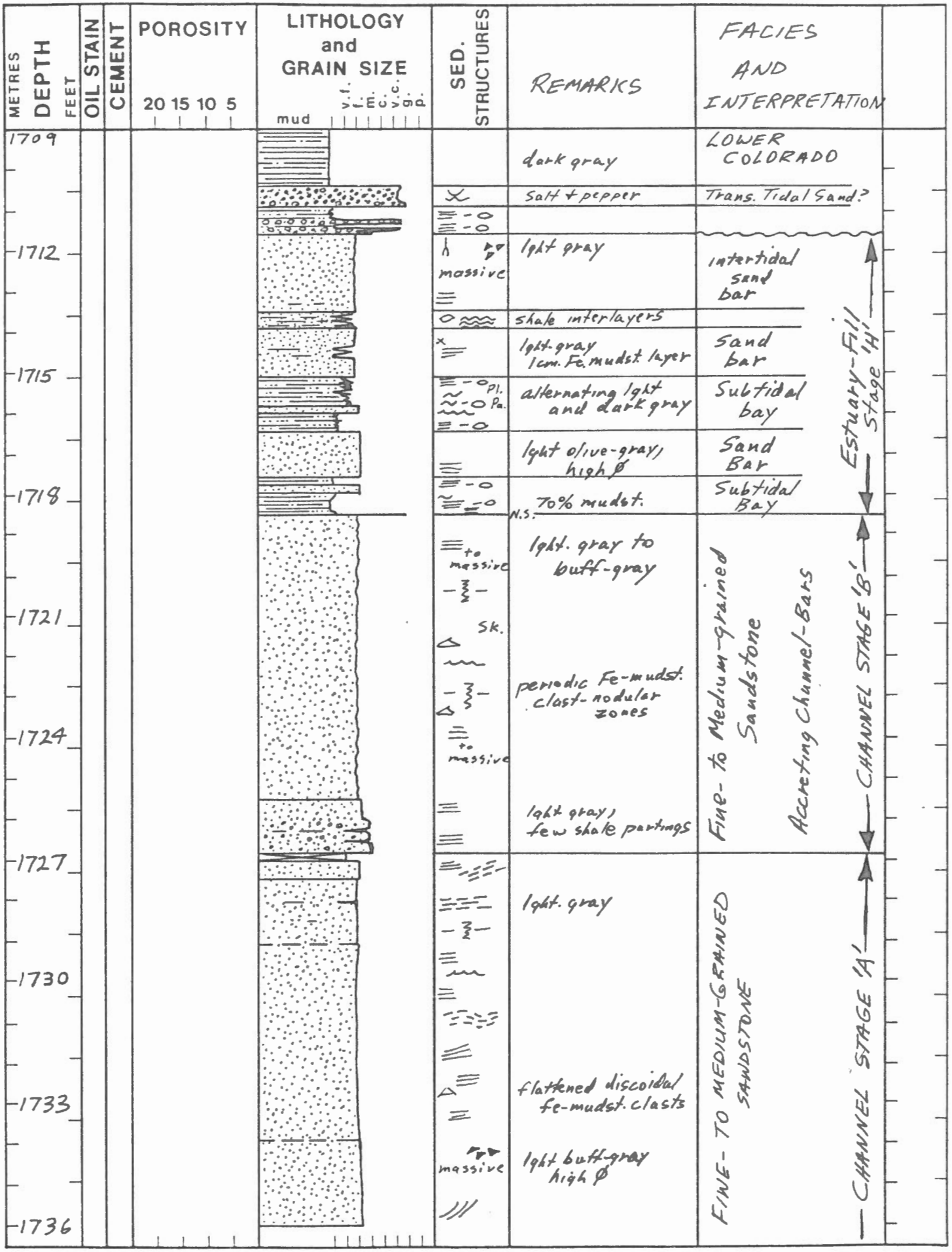
WELL NAME Westcoast et al Crystal (10cm diameter; unslabbed)

LOCATION 10-1-46-4W5 Continued CORE INTERVAL



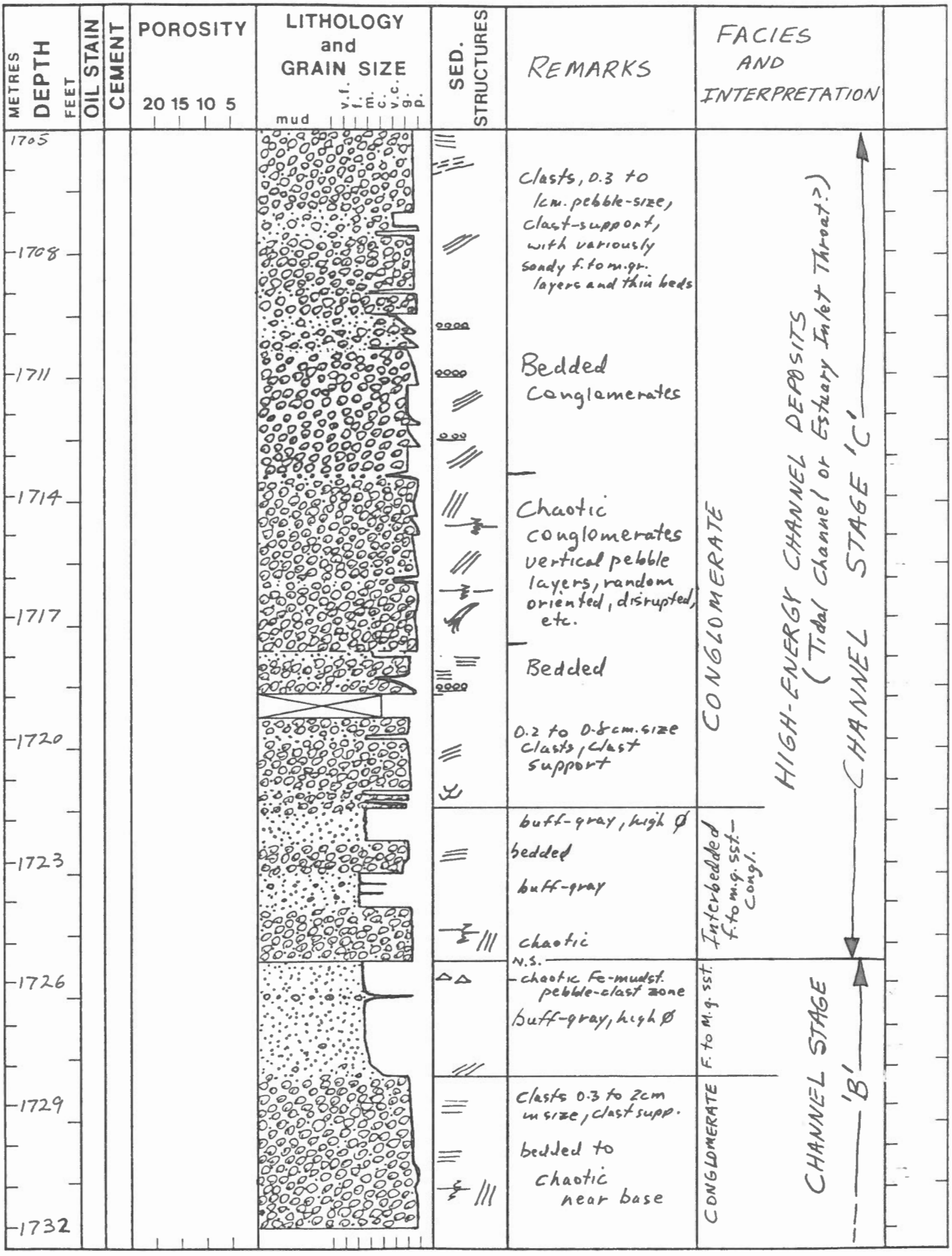
WELL NAME Reinecon Murphy Crystal

LOCATION 14-1-46-4w5 CORE INTERVAL 1709-1727 (Rec 16m) 1727-1739 (Rec 12m)



WELL NAME Westcoast et al Crystal (10cm diameter; slabbed)

LOCATION 16-1-46-4w5 CORE INTERVAL 1705-1719.5 (Rec 13.7m)
1719.5-1737.75 (Rec 17.5m)



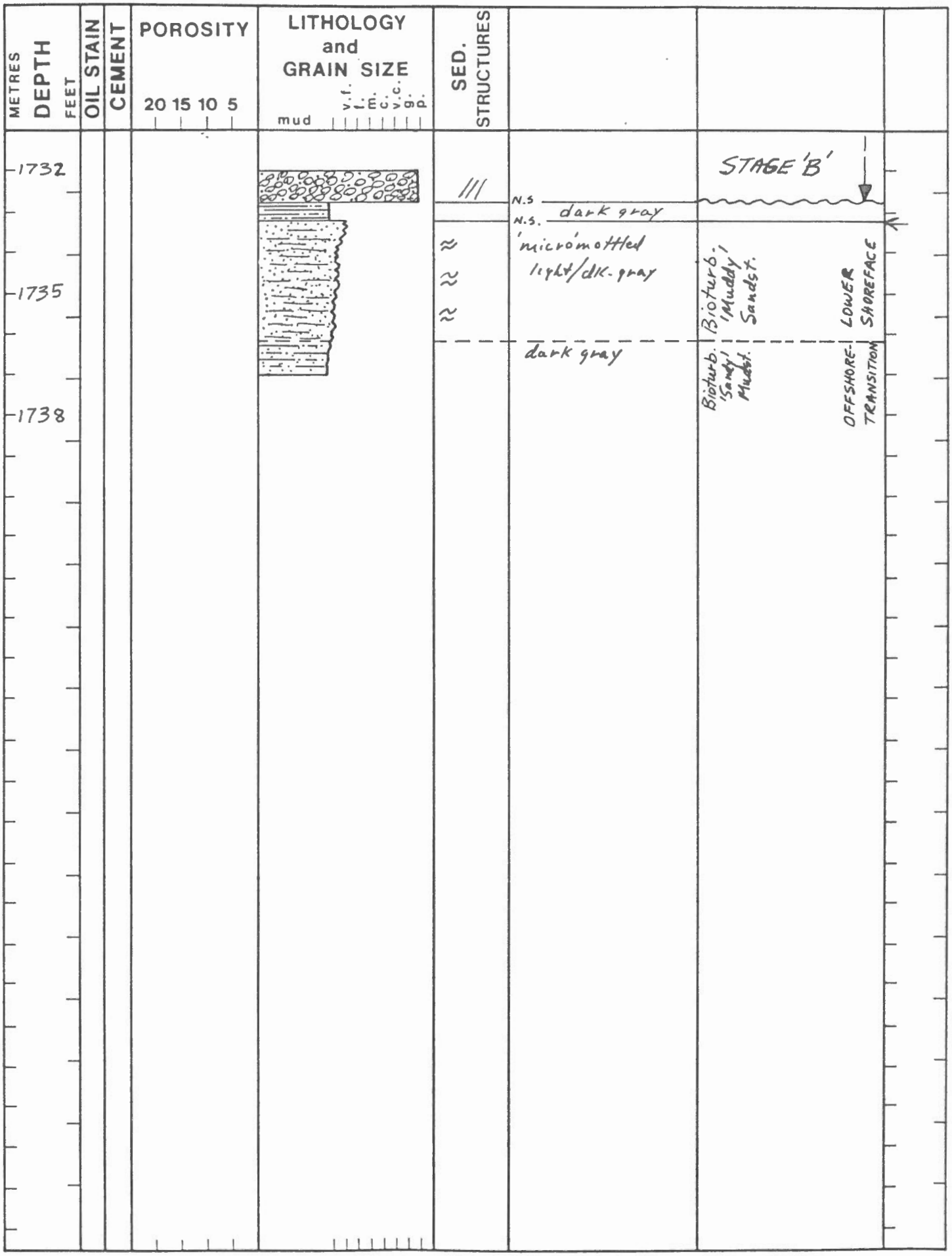
WELL NAME Petrocan Murphy Crystal

LOCATION 14-1-46-4W5 (Continued) CORE INTERVAL 1727-1739 (Rec 12m)

METRES DEPTH FEET	OIL STAIN	CEMENT	POROSITY 20 15 10 5	LITHOLOGY and GRAIN SIZE mud v.f. f. m. c. v.c. gr.	SED. STRUCTURES		
1736					massive	lgt. gray, rounded Fe-mudst. clasts	
					massive	light olive-brown, very high Ø clasts 0.2 to 0.7cm, clast-supported	Fining-Upward Channel Cycle Channel Floor STAGE 'A'
1739							
1742							

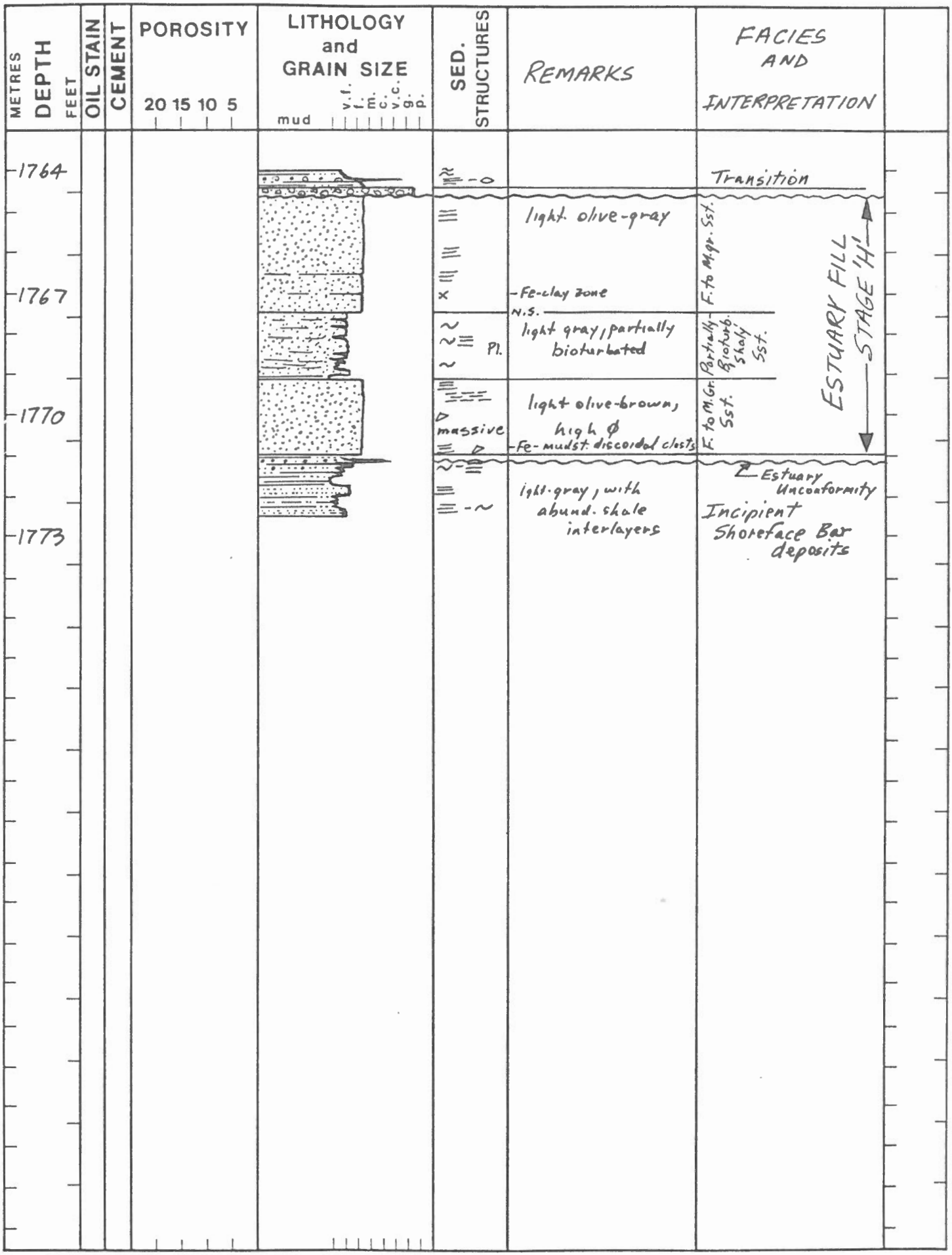
WELL NAME West coast et al Crystal

LOCATION 16-1-46-4 W5 (Continued) CORE INTERVAL 1719.5-1737.75 (Rec 17.5



WELL NAME Ucelot et al Crystal

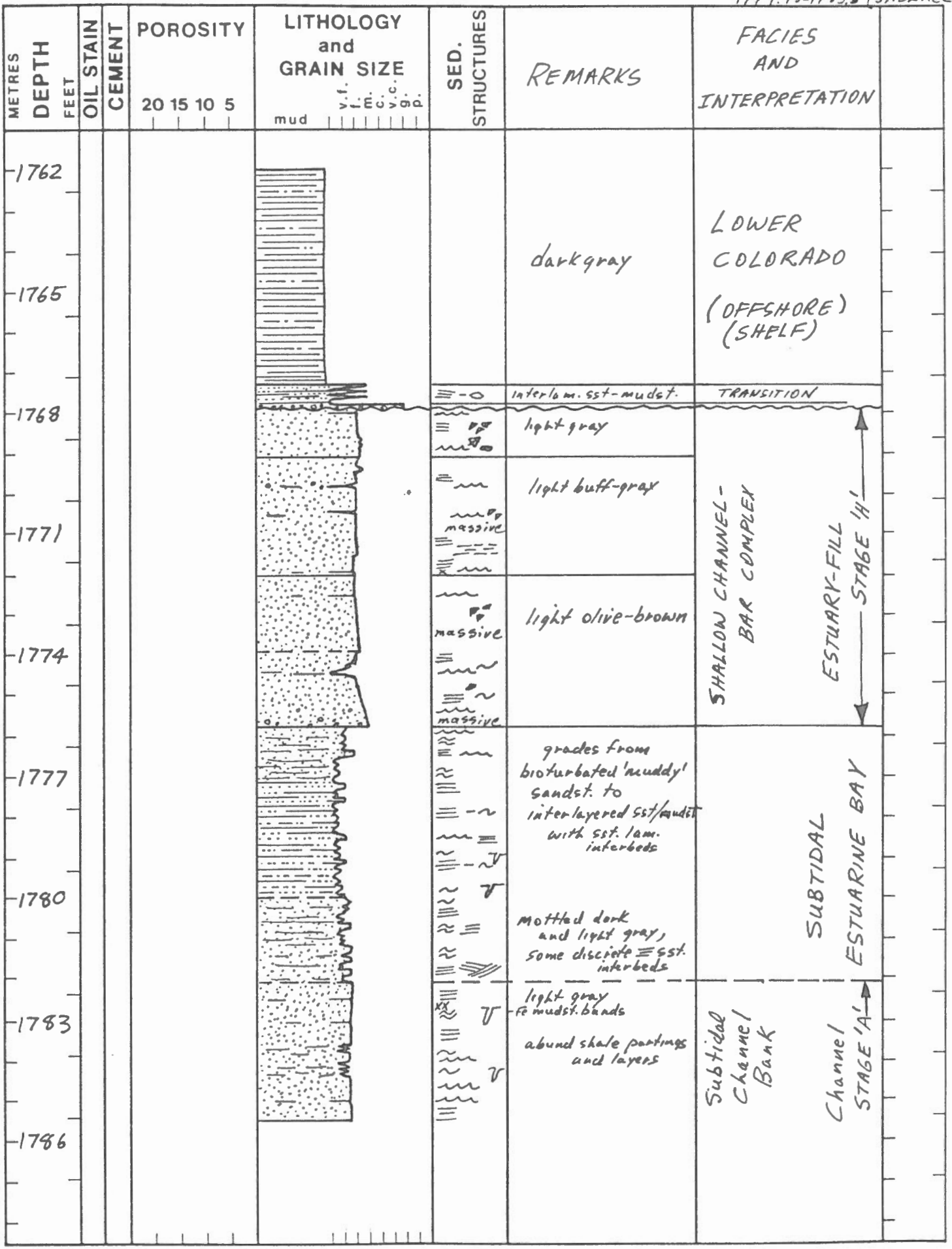
LOCATION 6-2-46-4W5 CORE INTERVAL 1764-1772.5



WELL NAME U.L.L. T/ Crystal

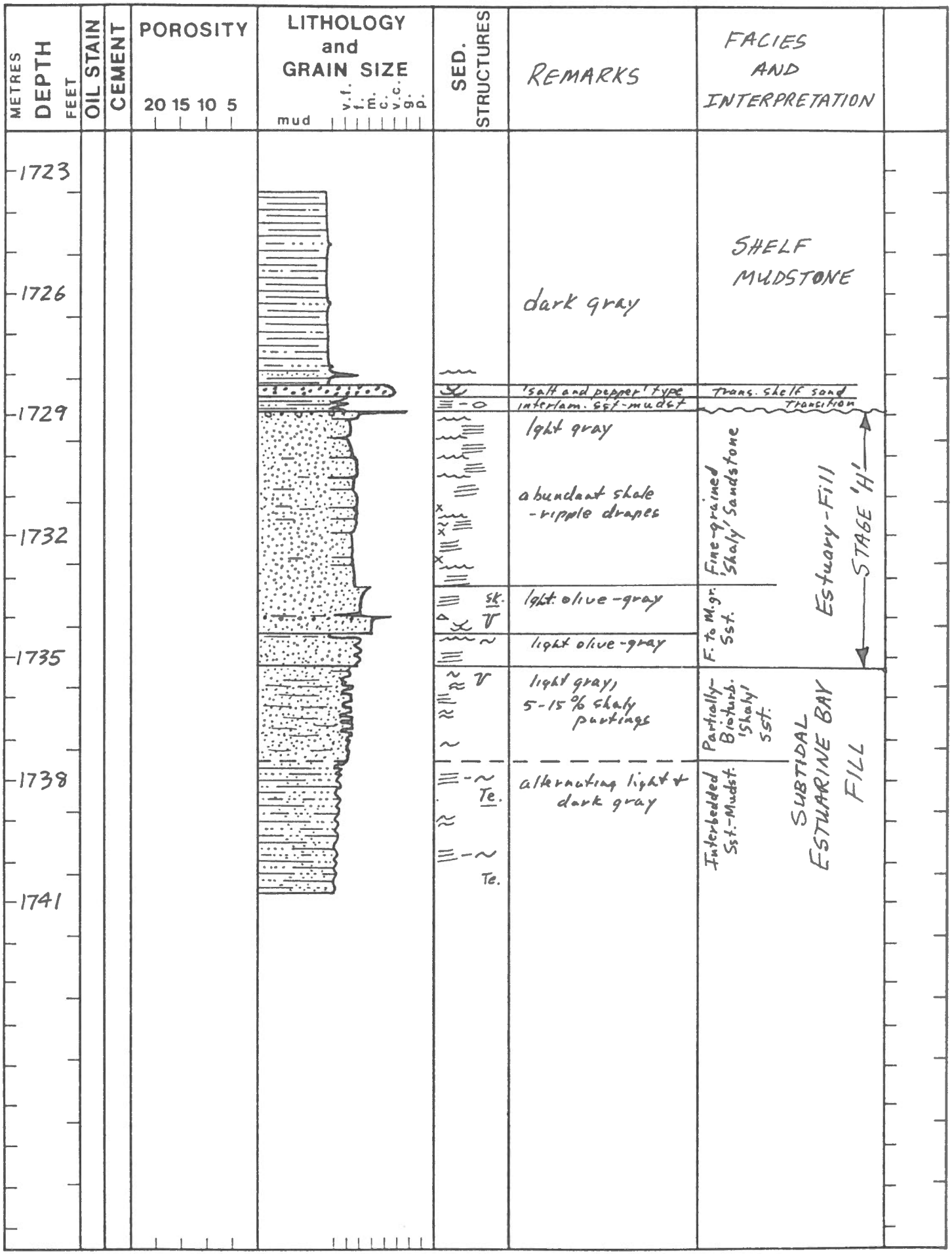
LOCATION 8-2-46-4W5

CORE INTERVAL 1762-1775.25 (13.25 m Rec)
1775.25-1779.75 (4.5 m Rec)
1779.75-1785.5 (5.75 m Rec)



WELL NAME O. I. L. Crystal

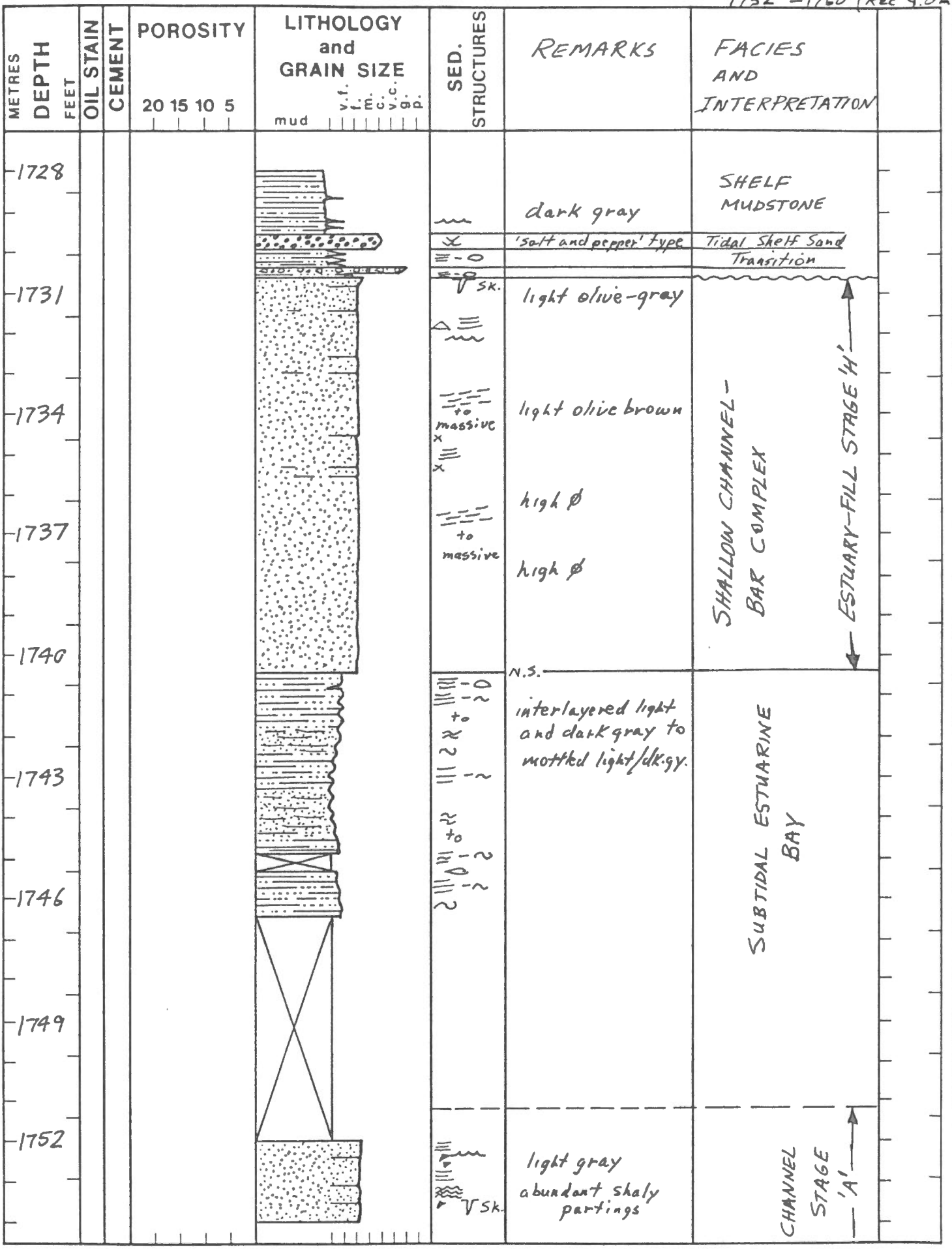
LOCATION 14-2-46-4W5 CORE INTERVAL 1723.5-1733.25 (Rec 9.75m)
1733.25-1740.75 (Rec 7.5m)



WELL NAME U.L.L. Crystal (8cm diameter; unslabbed)

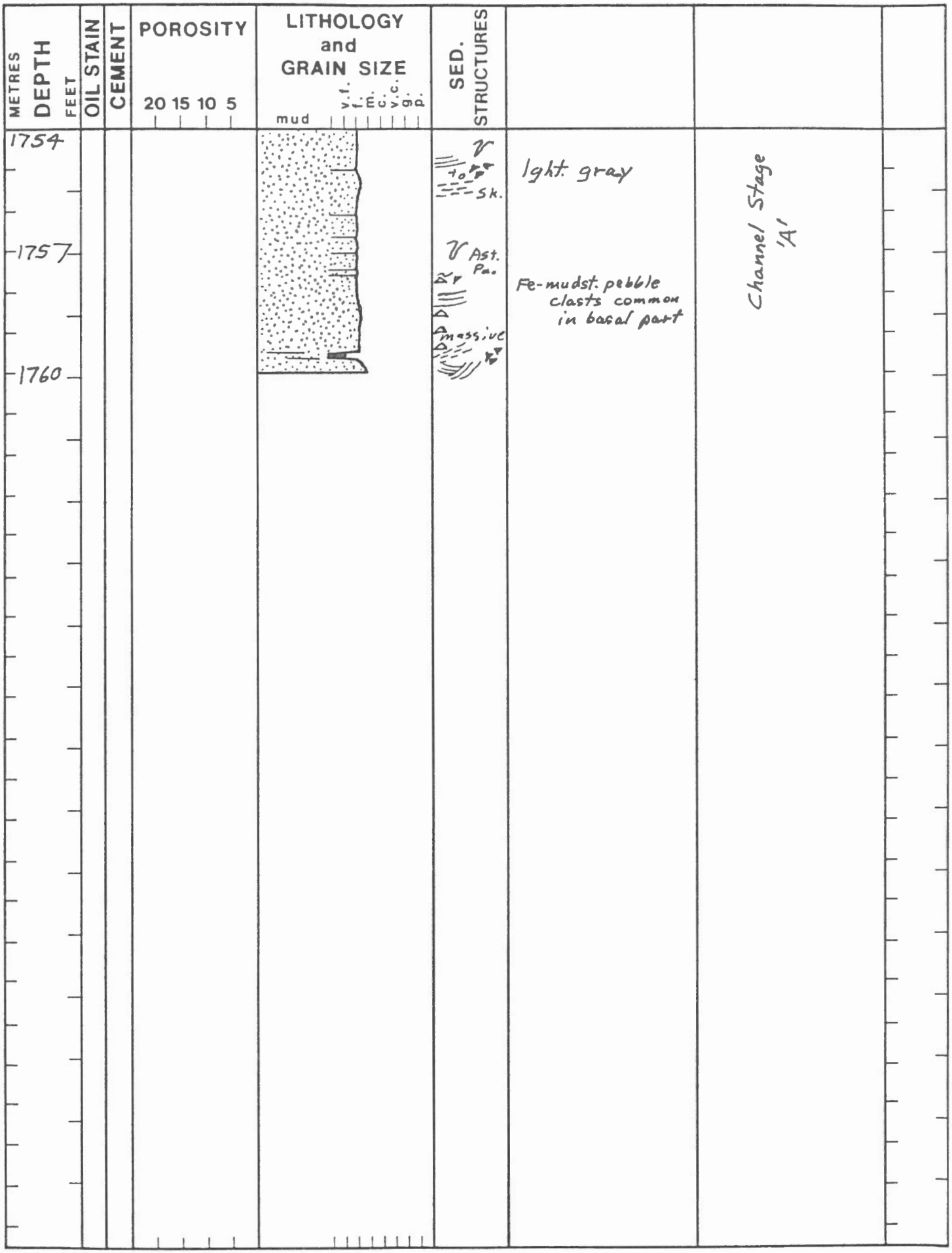
LOCATION 16-2-46-4W5

CORE INTERVAL 1728-1745.25 (Rec 16.8+)
1745.25-1746.75 (Rec 1.12-)
1752 -1760 (Rec 9.0-)



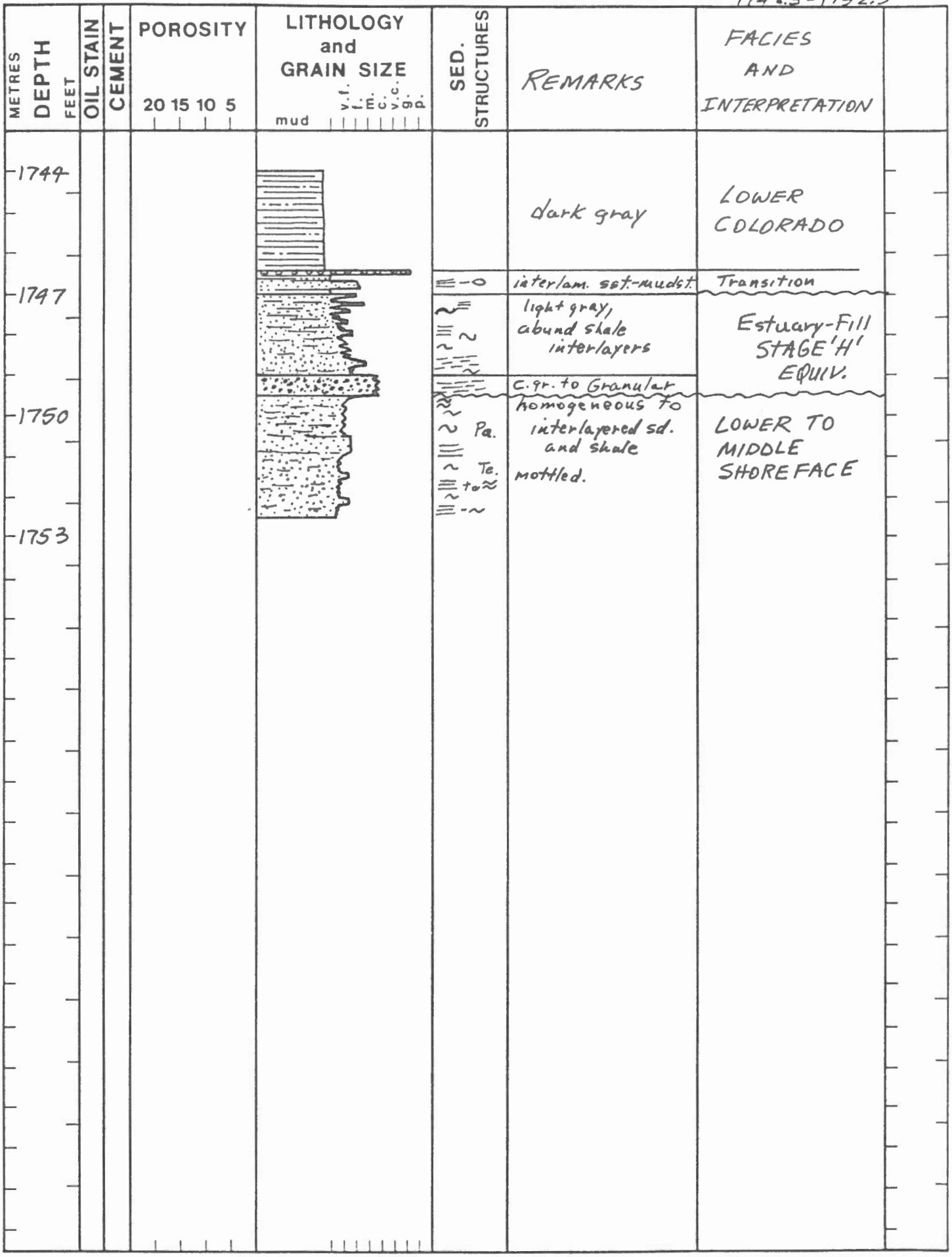
WELL NAME V.I.C. Crystal (8cm diameter; unslabbed)

LOCATION 16-2-46-4W5 (Continued) CORE INTERVAL



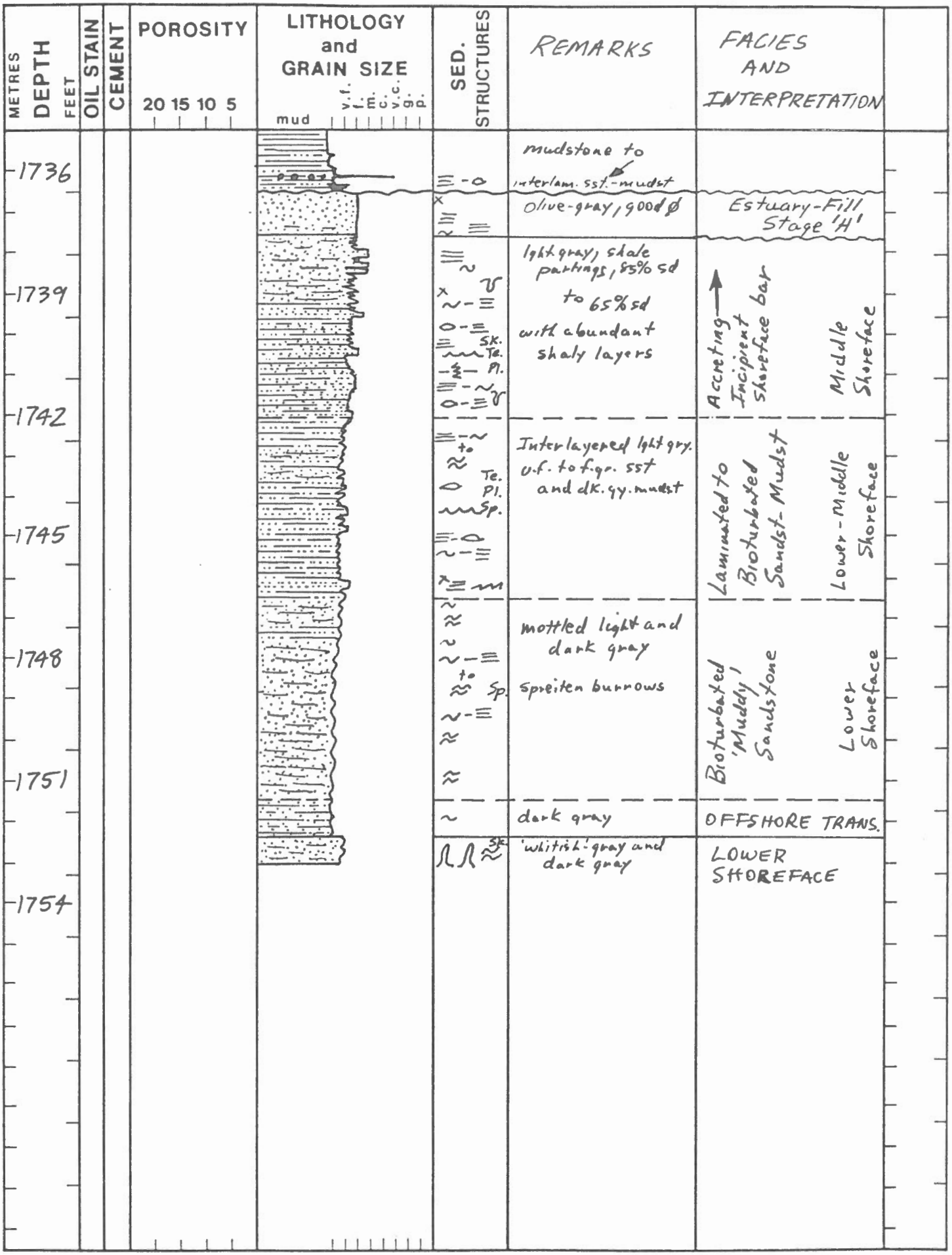
WELL NAME U.L.L. #1 Crystal (8.8 cm diameter; unslabbed)

LOCATION 8-3-46-4W5 CORE INTERVAL 1744 - 1748 / 1748 - 1748.5 / 1748.5 - 1752.5



WELL NAME U.L.L. 41 Crystal

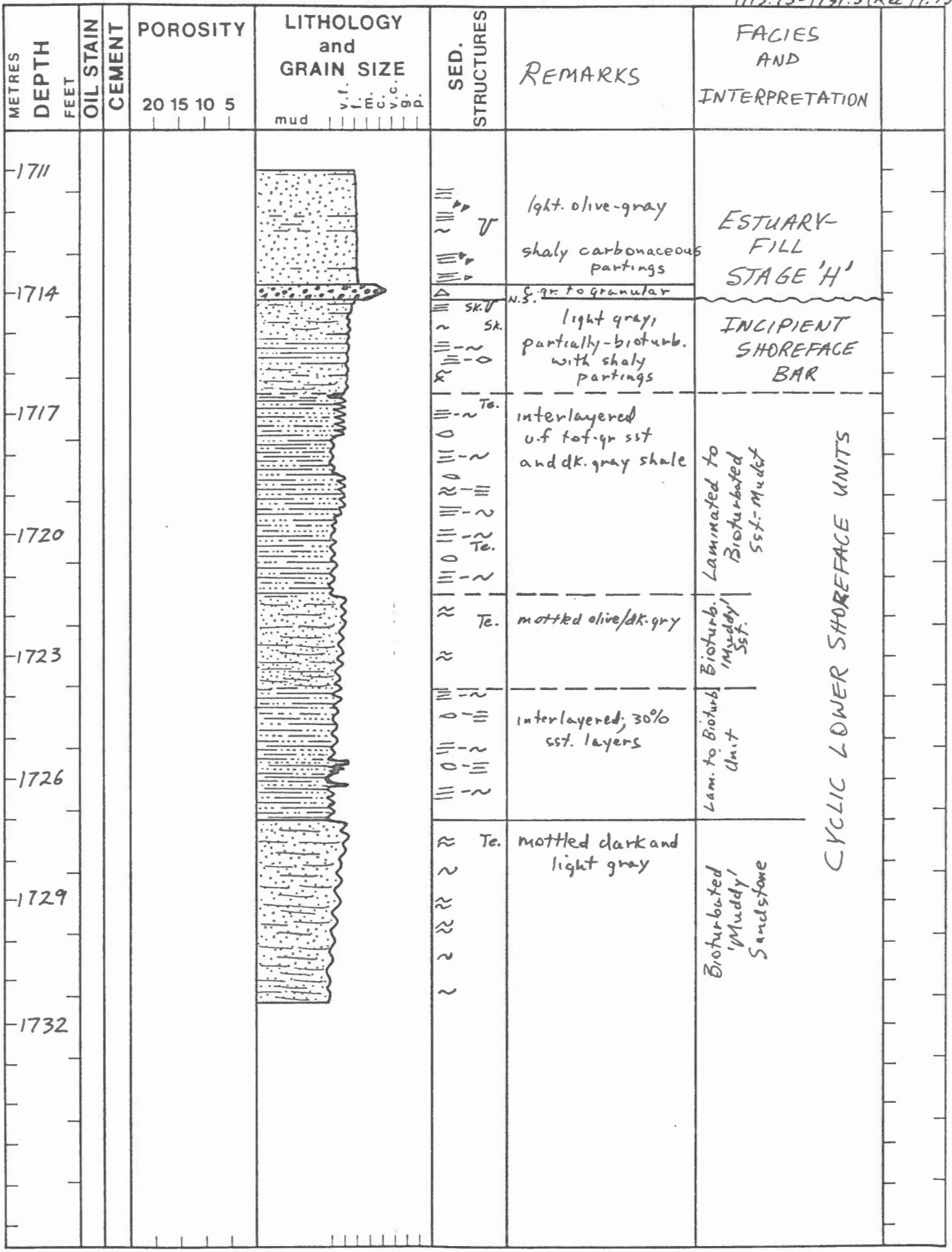
LOCATION 16-3-46-4W5 CORE INTERVAL 1735-1753 (Rec 18m)



WELL NAME O.I.L. 20 Crystal (8cm diameter, unslabbed)

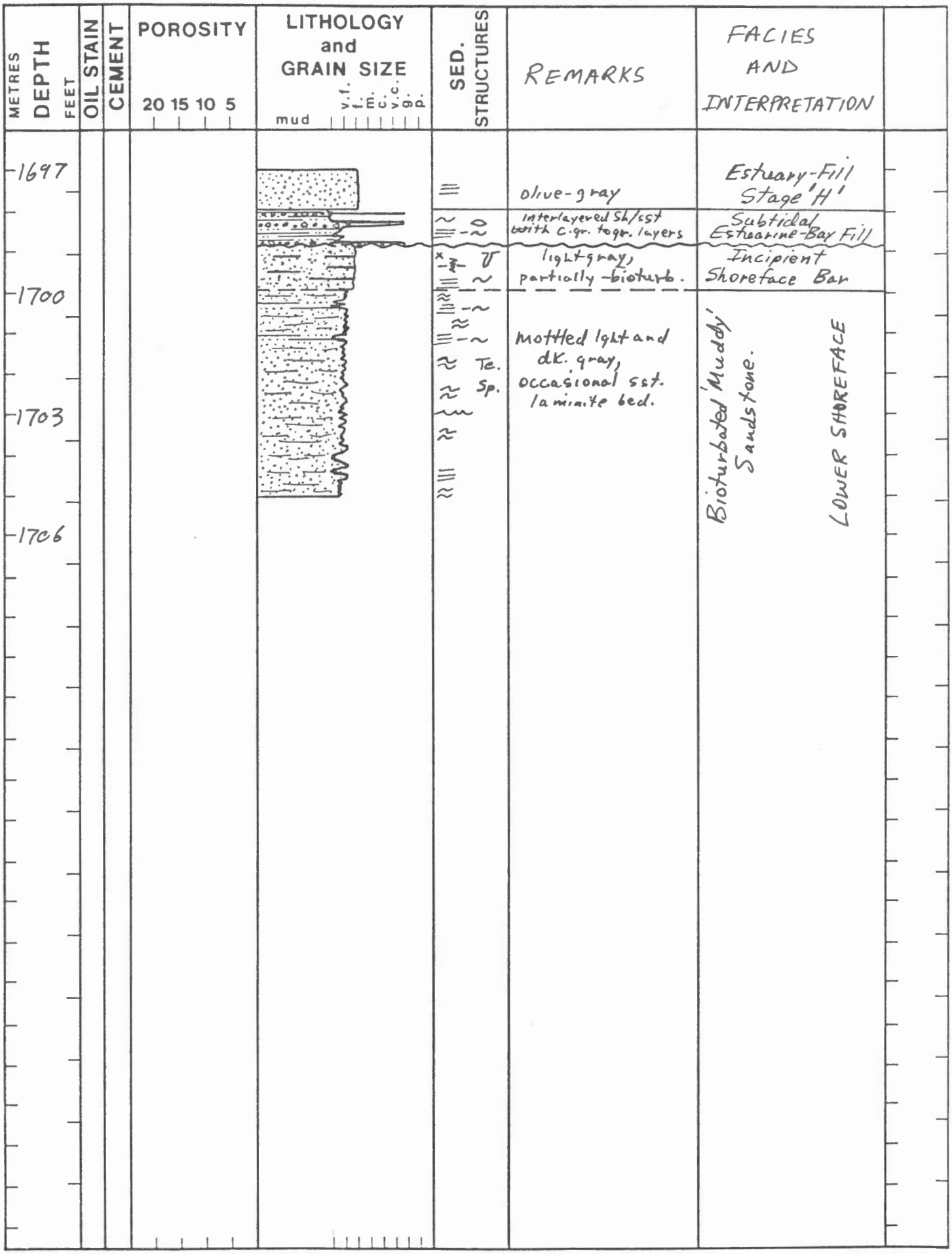
LOCATION 8-10-46-4W5

CORE INTERVAL 1711-1711.5 (Rec 0.5m)
1711.5-1713.75 (Rec 2.25m)
1713.75-1731.5 (Rec 17.75m)



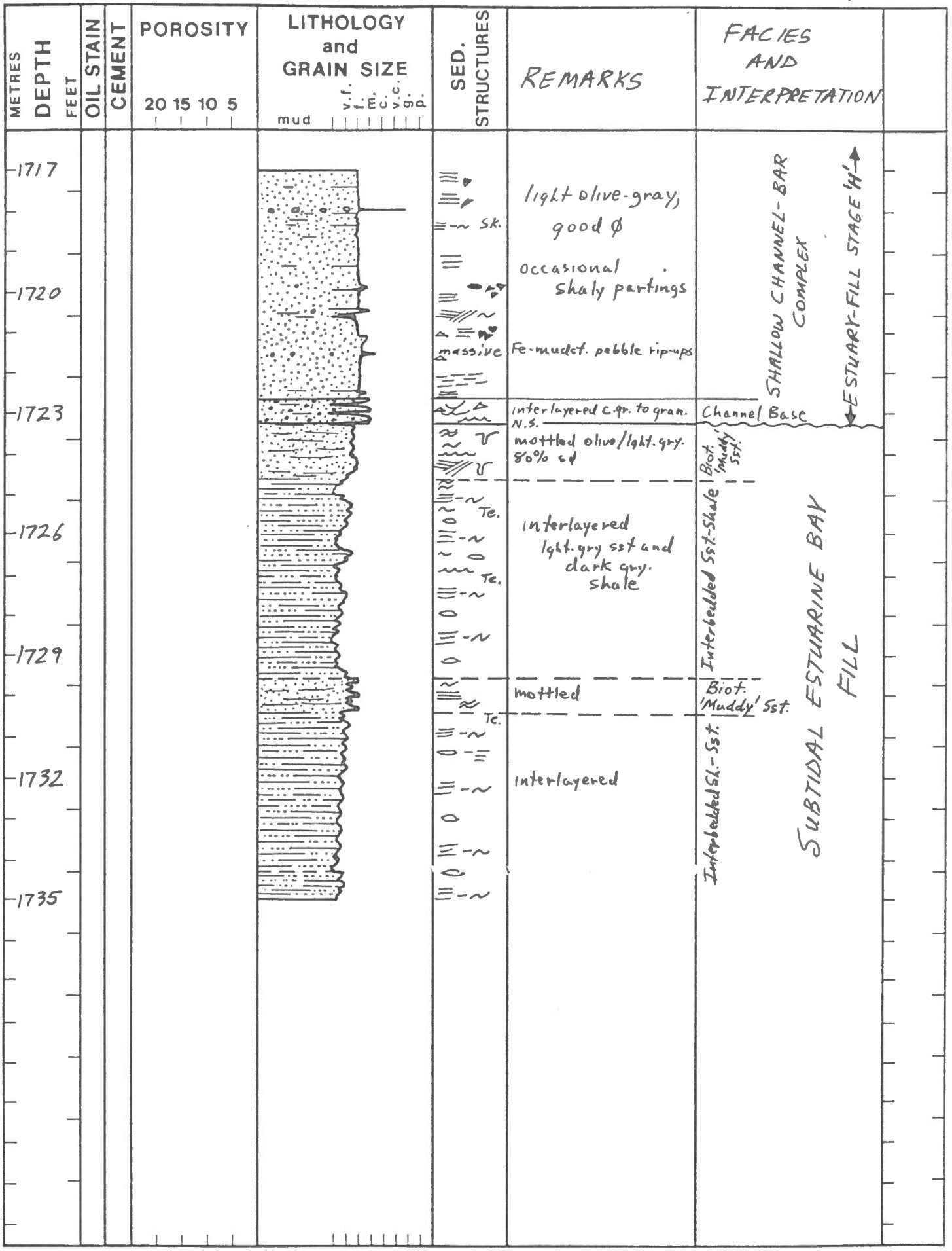
WELL NAME U.L.L. et al. 41 Crystal

LOCATION 16-10-46-4W5 CORE INTERVAL 1697-1705 (Rec 8m)



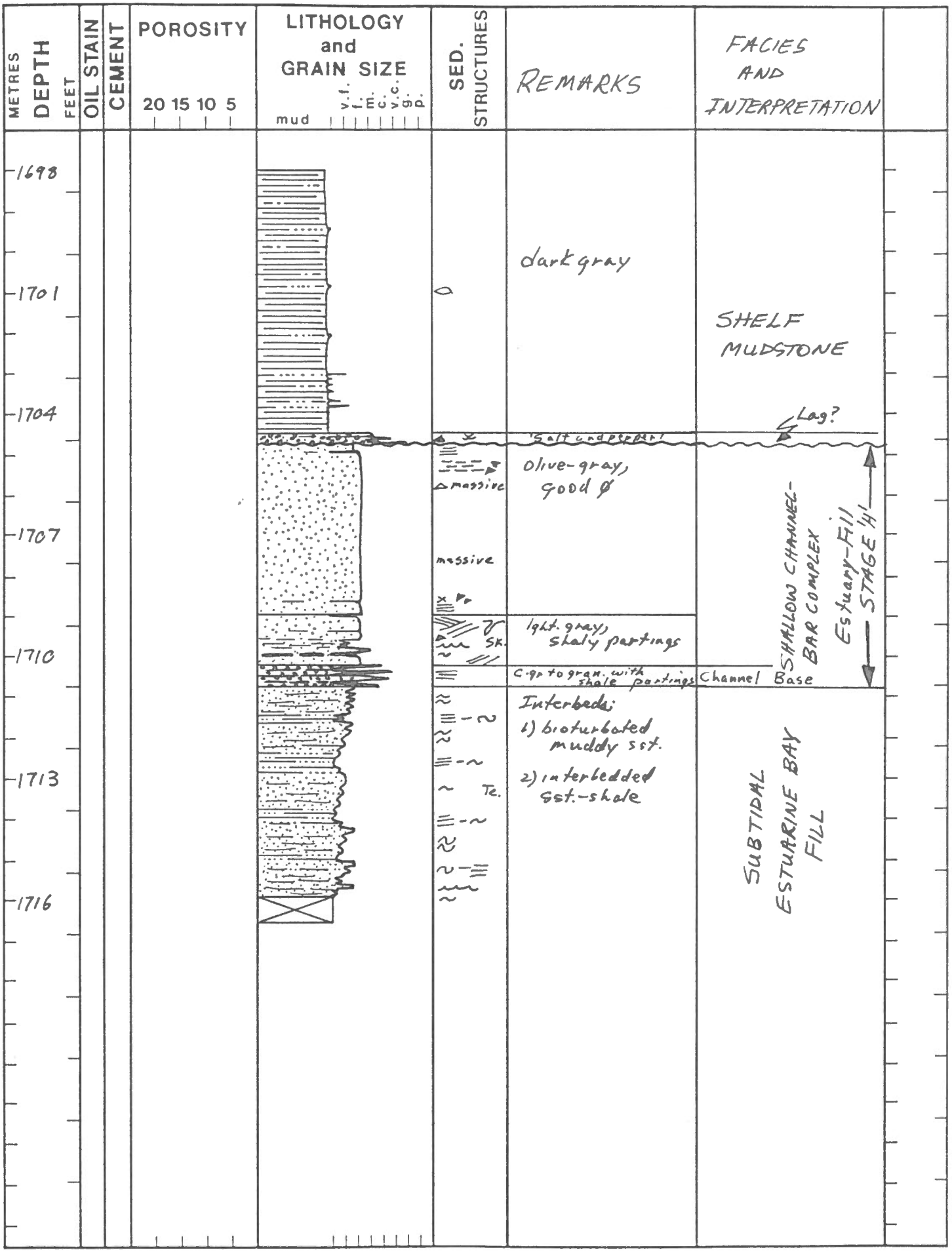
WELL NAME Westcoast Bluesky Crystal

LOCATION 6-11-46-4W5 CORE INTERVAL 1717-1735 (Rec 18m)



WELL NAME Westcoast Bluesky Crystal (10cm diameter, unslabbed)

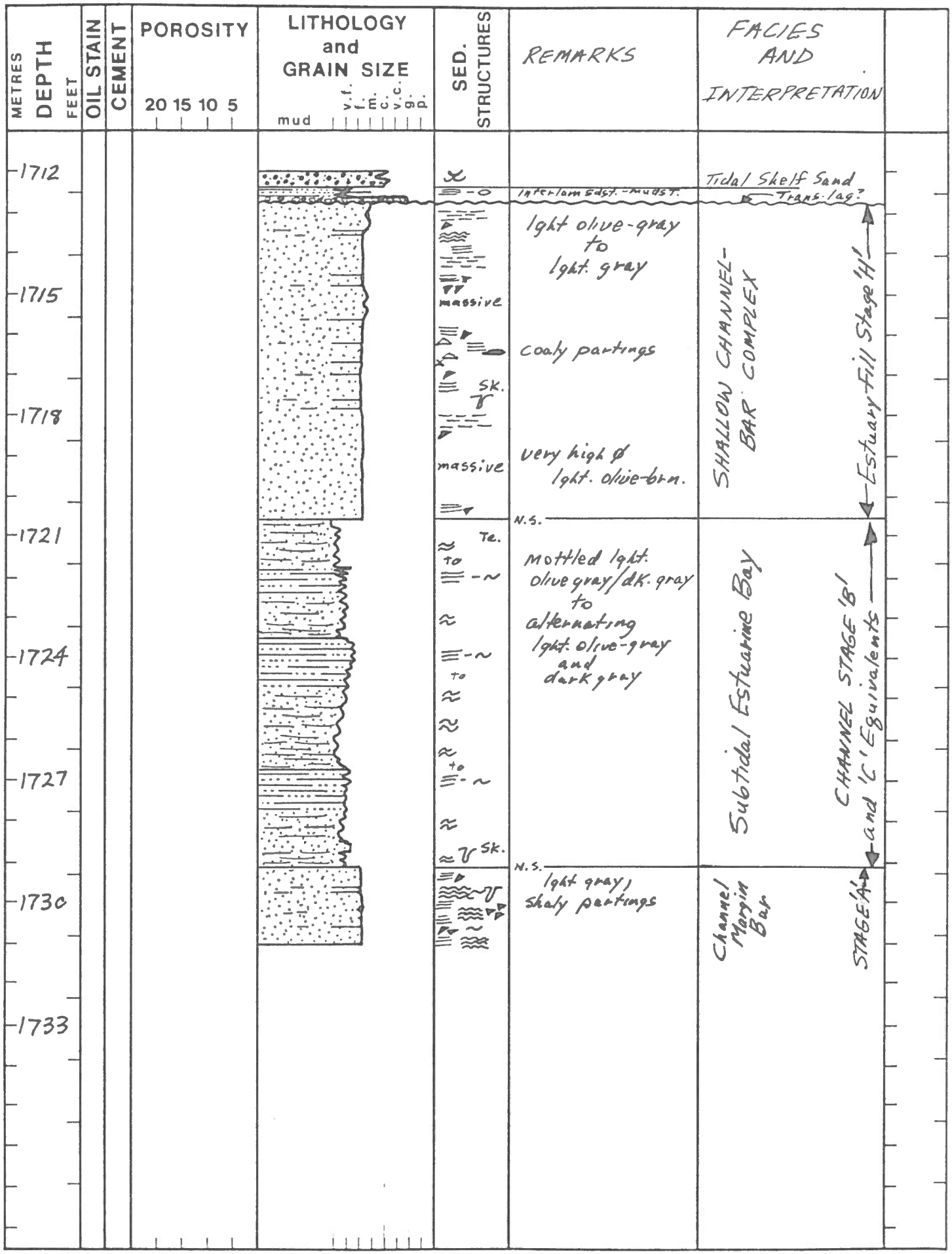
LOCATION 14-11-46-4W5 CORE INTERVAL 1698-1698.25 (Rec 0.25m)
1698.25-1716.5 (Rec 17.6m)



WELL NAME Westcoast Bluesky Crystal

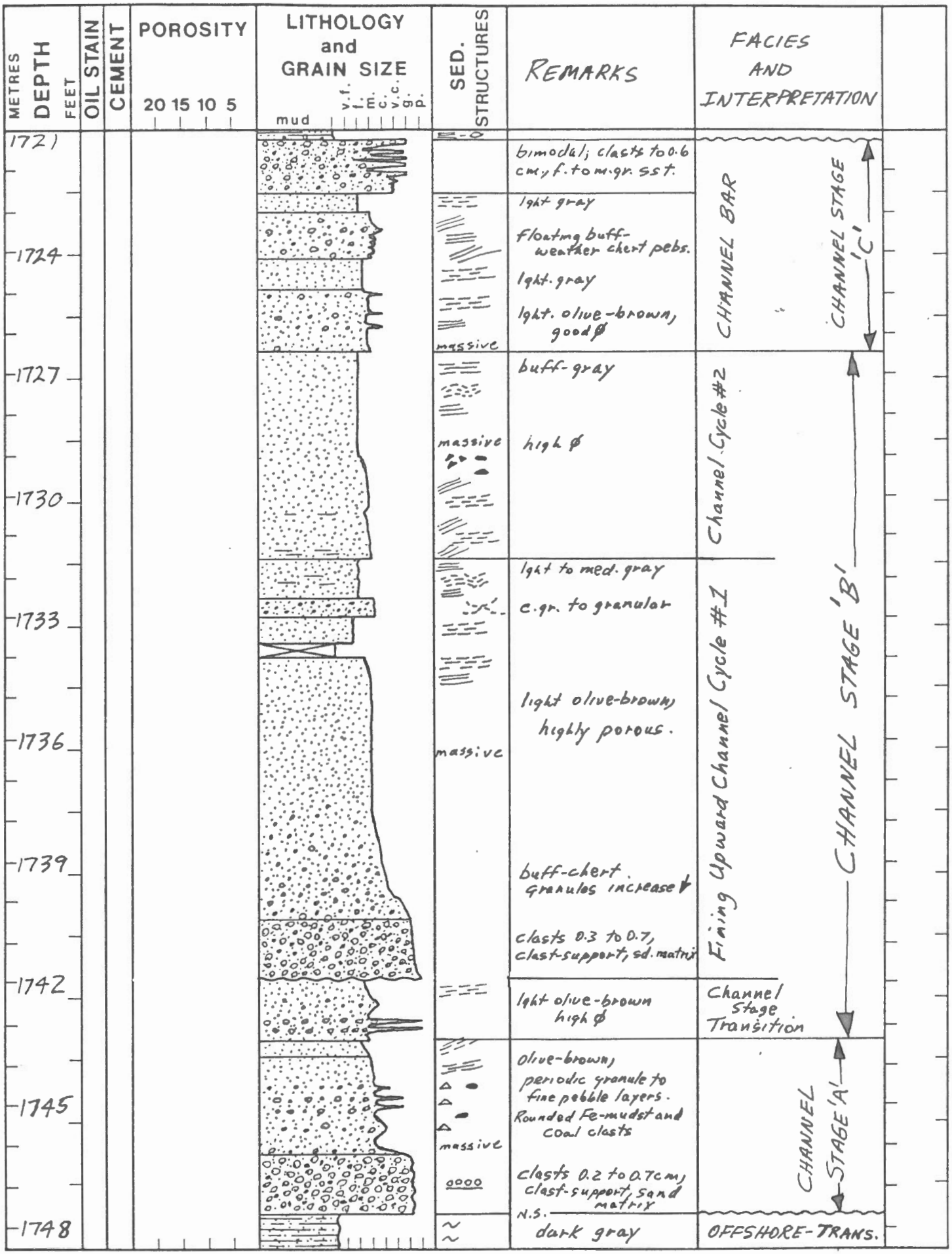
LOCATION 8-11-46-4W5

CORE INTERVAL 1712-1730.2 (Rec 18.2m)
1730.2-1731.05 (Rec 0.85m)



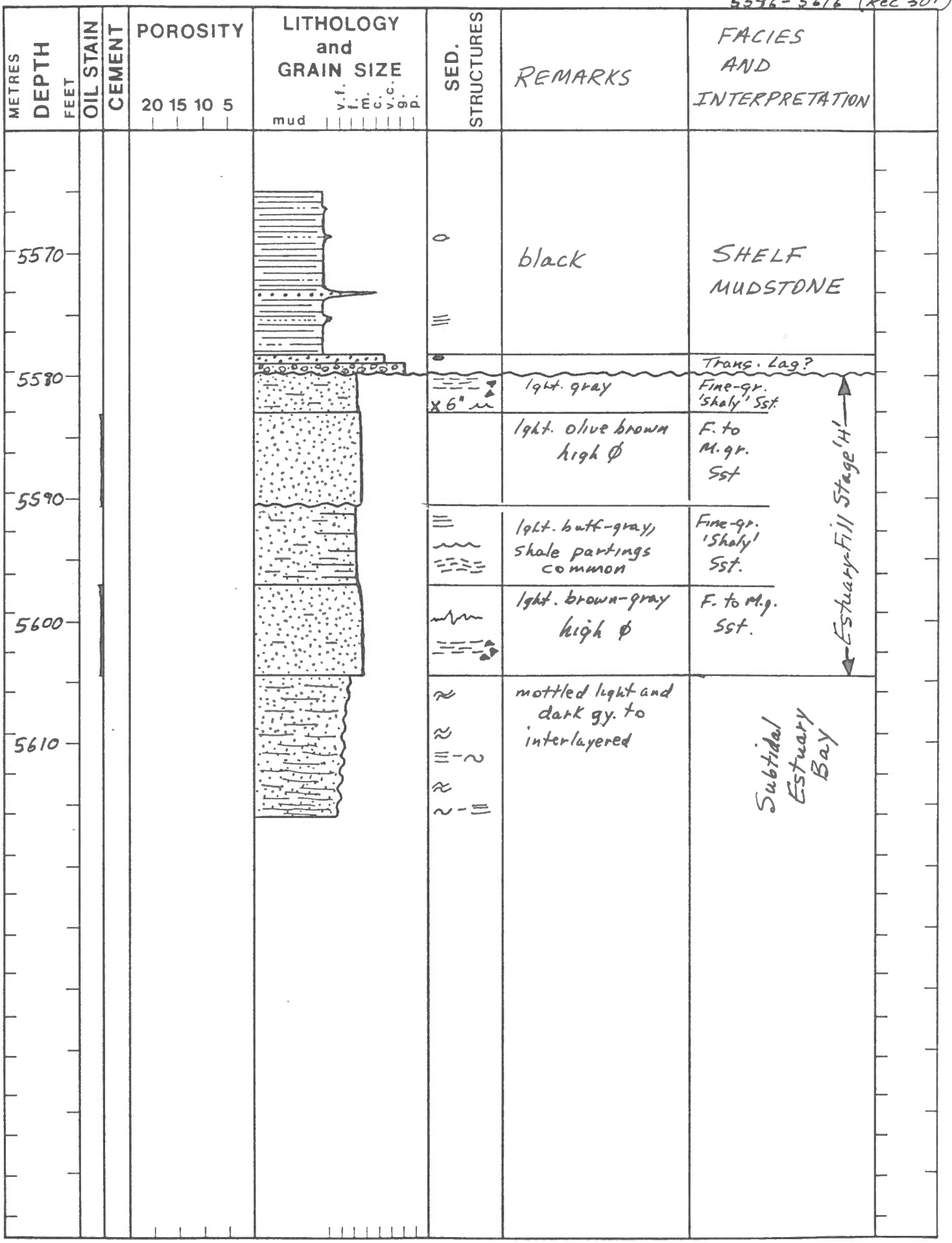
WELL NAME Westcoast et al. Rembina (8 cm diameter; slabbed)

LOCATION 8-12-46-4W5 CORE INTERVAL 1721-1734 (Rec 12.7m)
1734-1752 (Rec 17.35m)



WELL NAME Focus et al. Wintield (10cm diameter; slabbed)

LOCATION 11-12-46-4W5 CORE INTERVAL 5565-5585 (Rec 20')
5585-5586 (Rec 0.7')
5596-5616 (Rec 30')



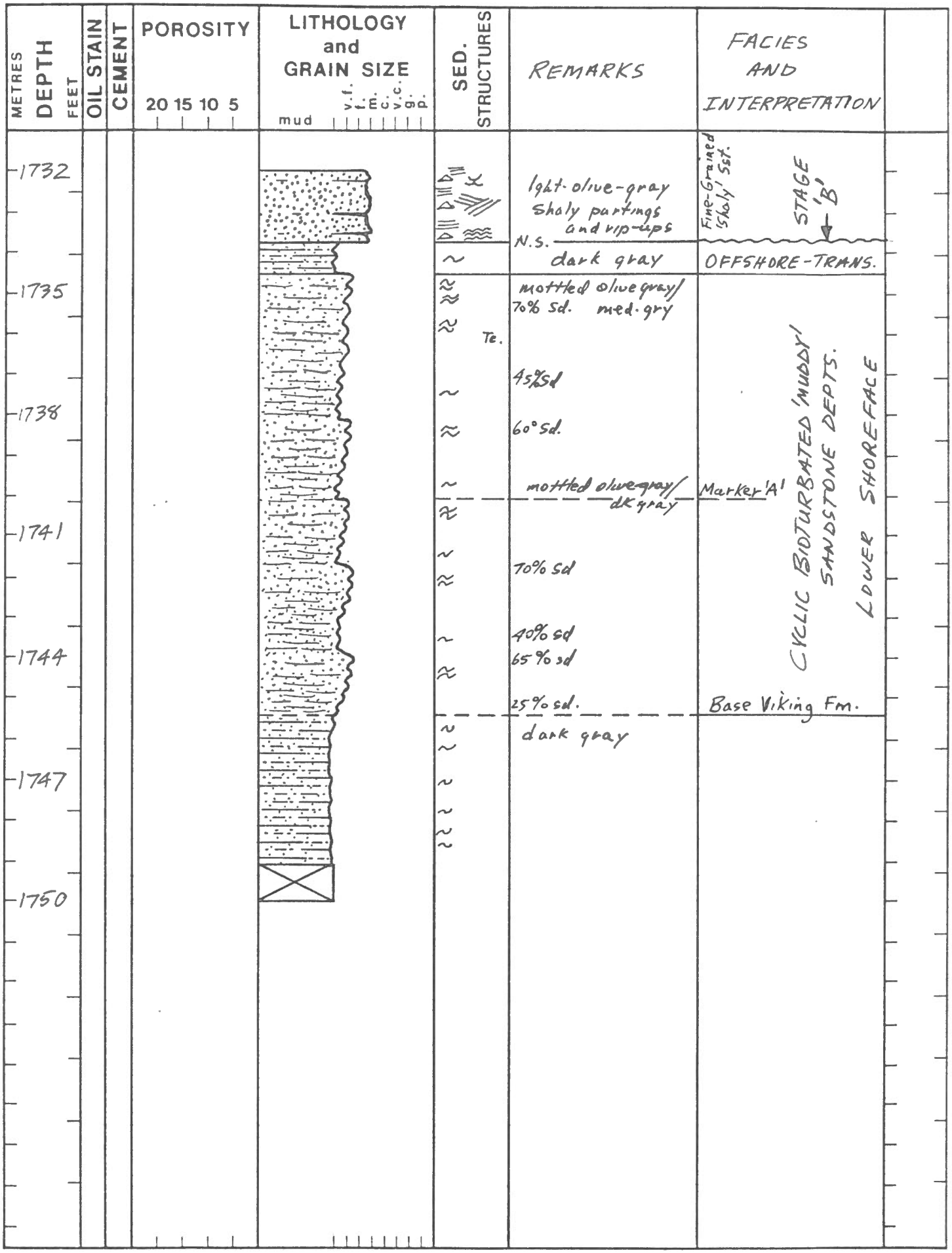
WELL NAME Westcoast CT al Crystal (10cm diameter, unslabbed)

LOCATION 8-13-46-4W5 CORE INTERVAL 1692 - 1699.25 (Rec 6.2m)
1699.25 - 1701 (Rec 1.75m)

METRES DEPTH FEET	OIL STAIN	CEMENT	POROSITY 20 15 10 5	LITHOLOGY and GRAIN SIZE mud v.f. f. m. c. v.c. g.p.	SED. STRUCTURES	REMARKS	FACIES AND INTERPRETATION
1692						interlayered light v.f. to f.gr sst., and dk.gry. mudst.	Subtidal Estuarine Muddy Facies
1695					V sk.		
1698					N.S.	light gray c.gr. to granular, with several 0.5-2cm. size mudst. rip-up clasts	Channel Edge — CHANNEL STAGE 'B'
1701					V sk.	light gray, numerous shaly partings	channel marginal bank depts.

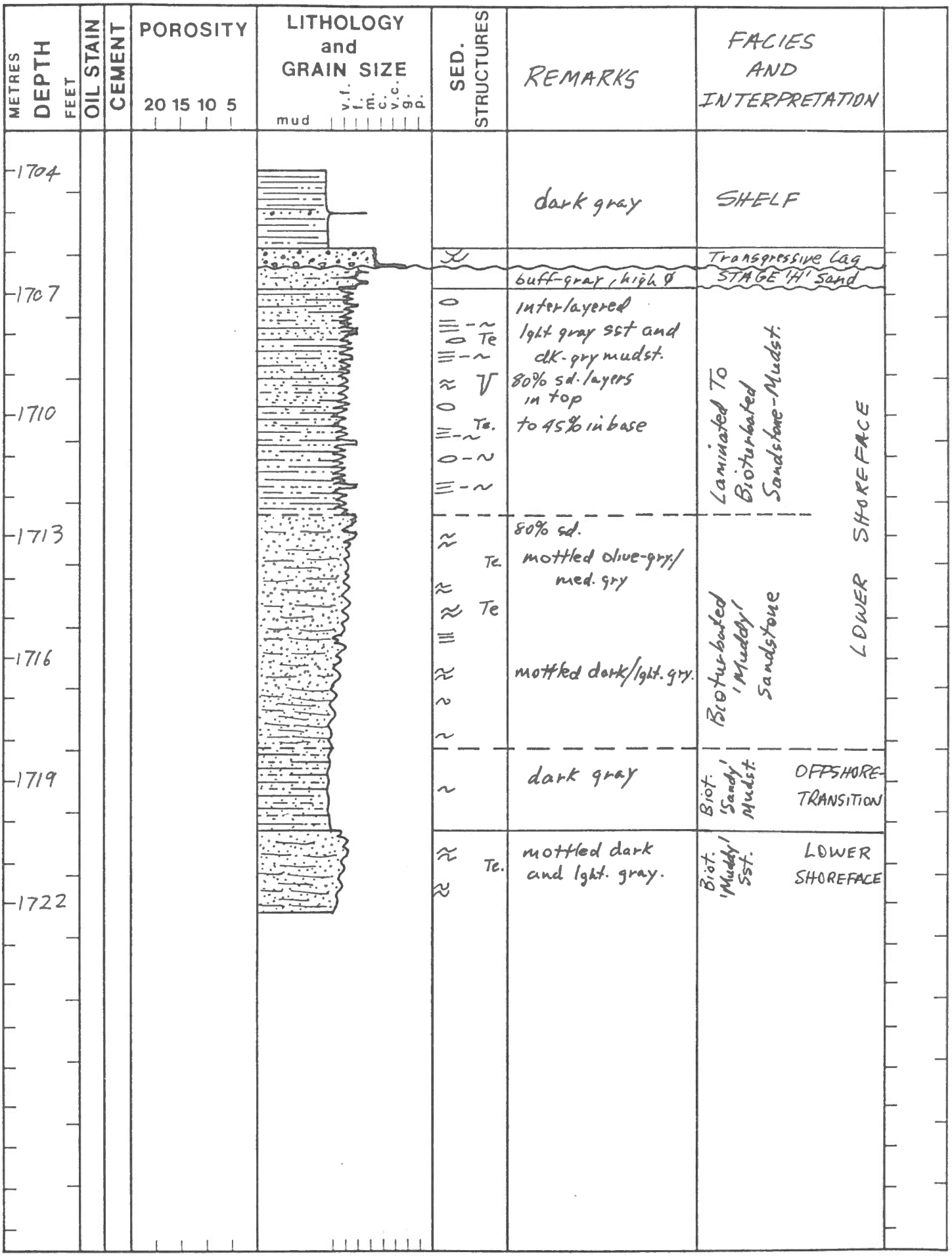
WELL NAME Westcoast et al Crystal

LOCATION 16-13-46-4w5 CORE INTERVAL 1732-1750 (Rec 17.1m)



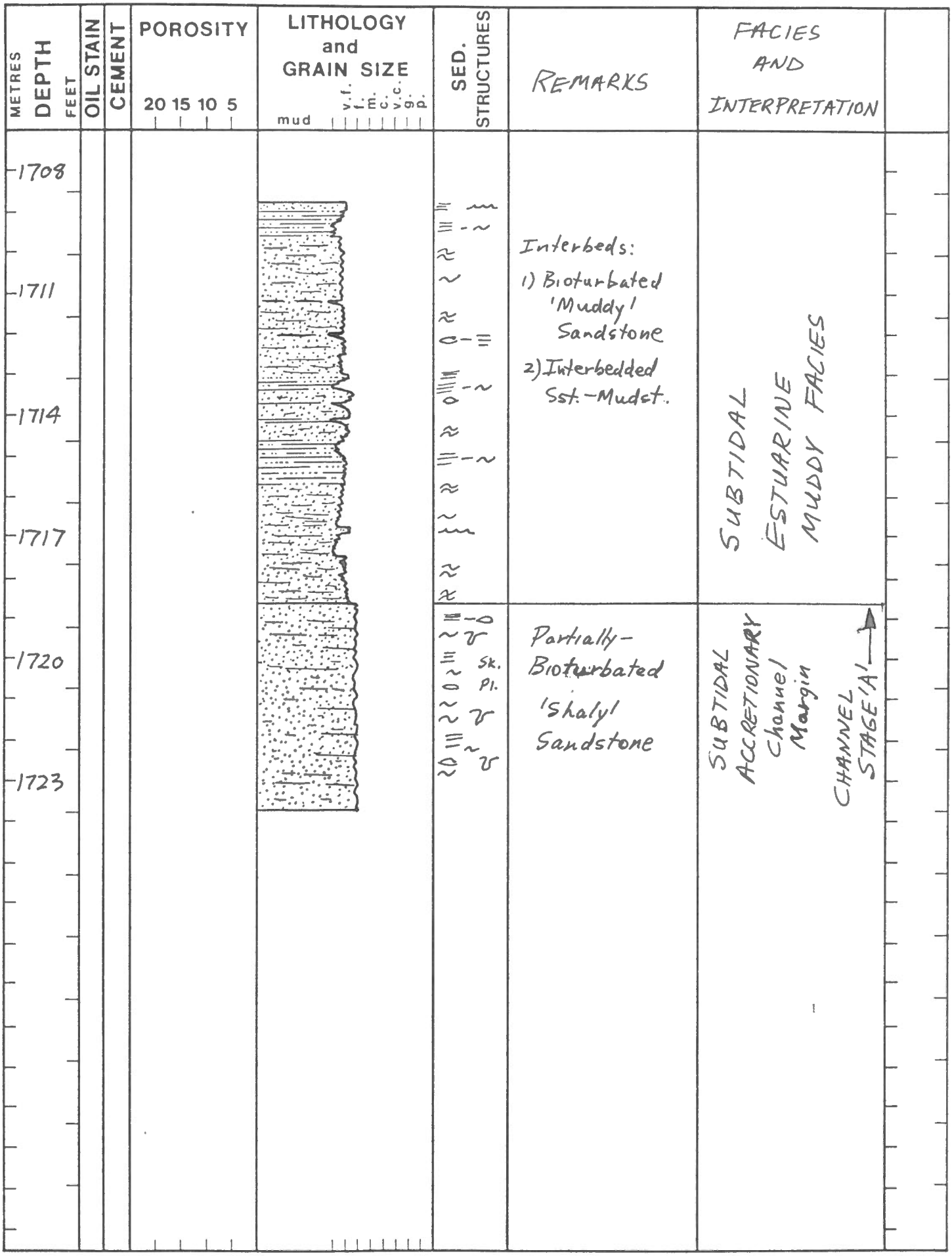
WELL NAME Blue Sky et al Crystal (8cm diameter; unslabbed)

LOCATION 8-15-46-4 w5 CORE INTERVAL 1704 - 1722.2 (Rec 18.



WELL NAME Westcoast et al. Crystal (10cm diameter; unslabbed)

LOCATION 6-24-46-4W5 CORE INTERVAL 1708.75-1723.75

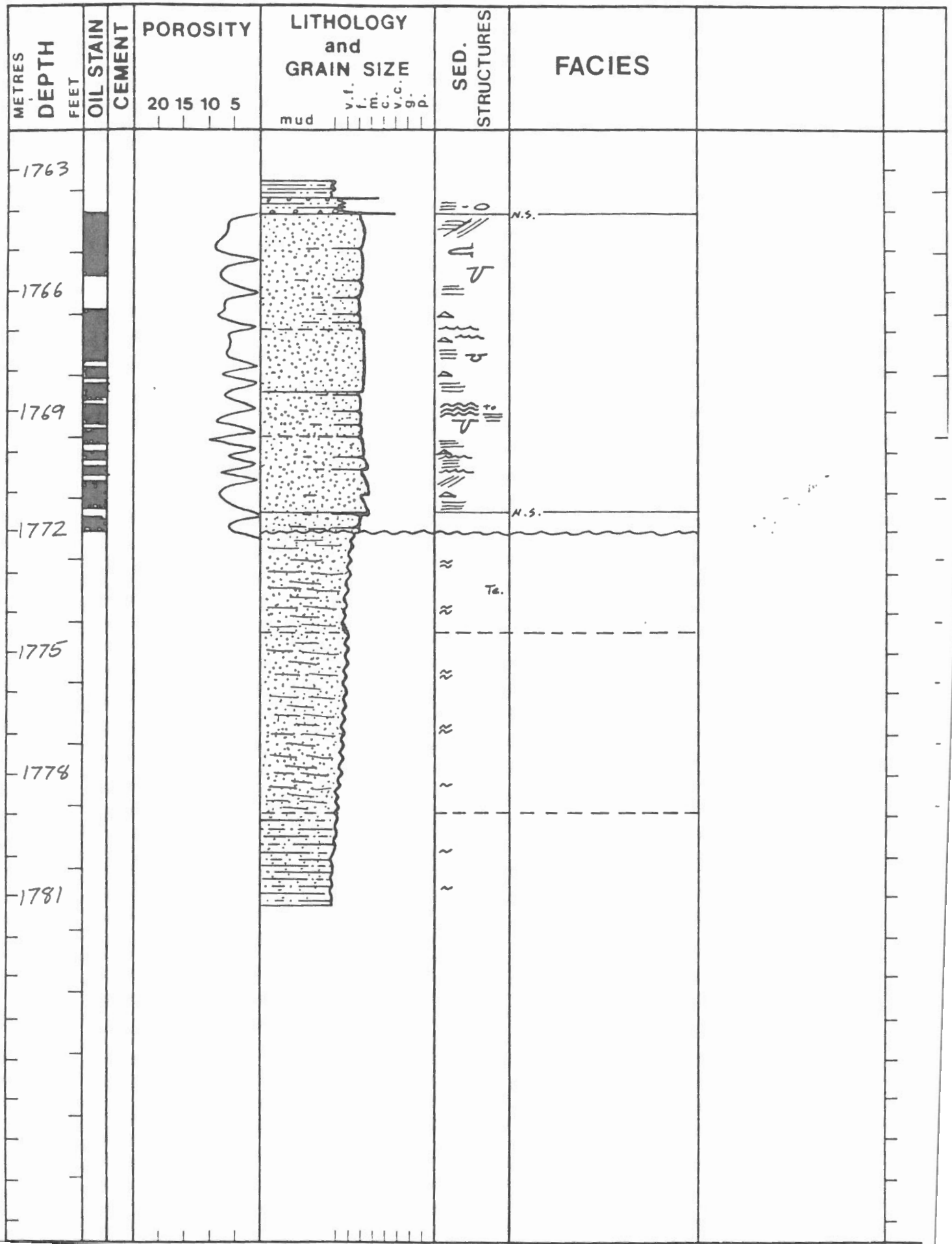


APPENDIX II

Depth plots of core-analysis data from selected well cores

WELL NAME Decalta et al Crystal (4" diameter; unslabbed)

LOCATION 14-20-45-3w5 CORE INTERVAL 1763.25-1781.25 (Rec 18.0m)

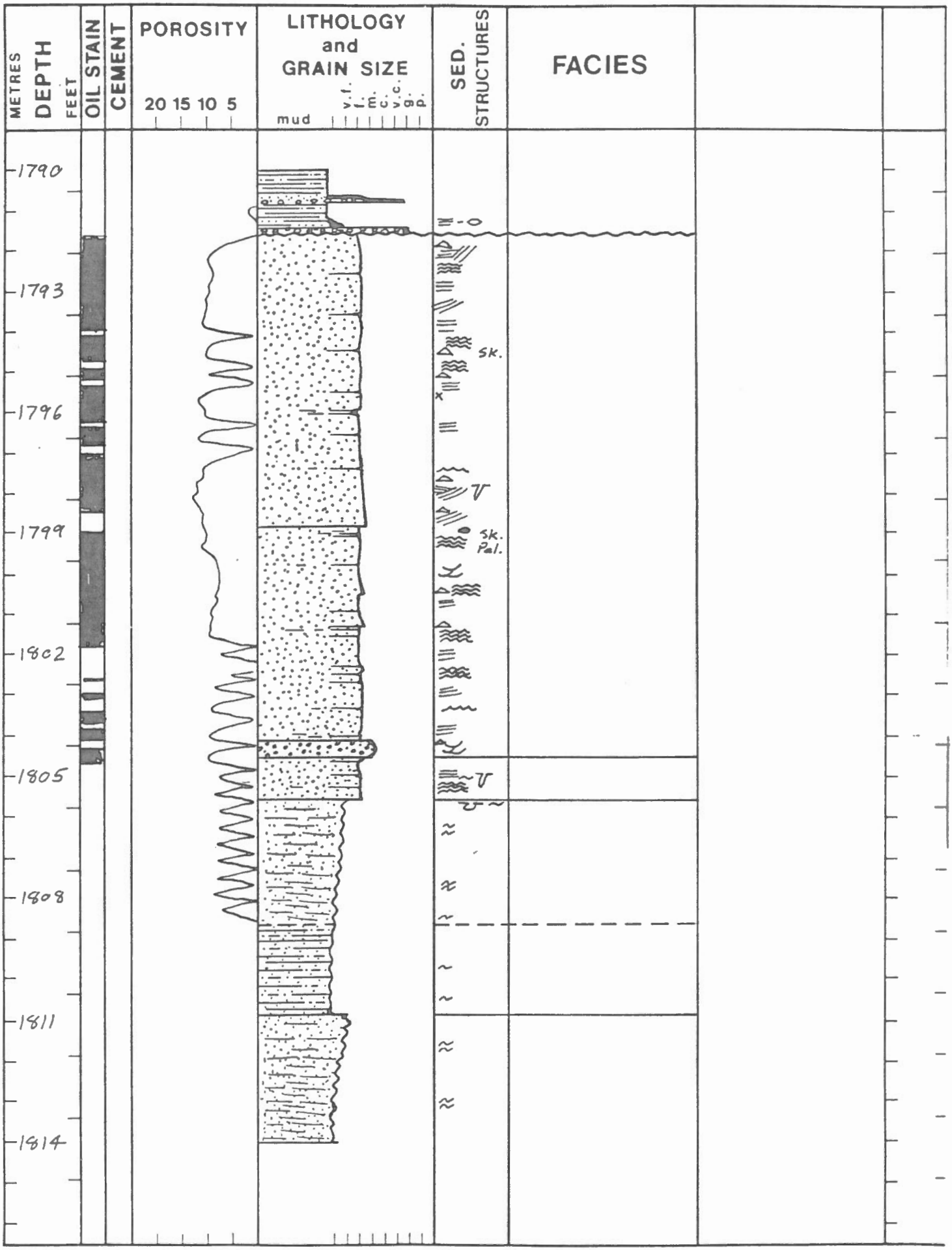


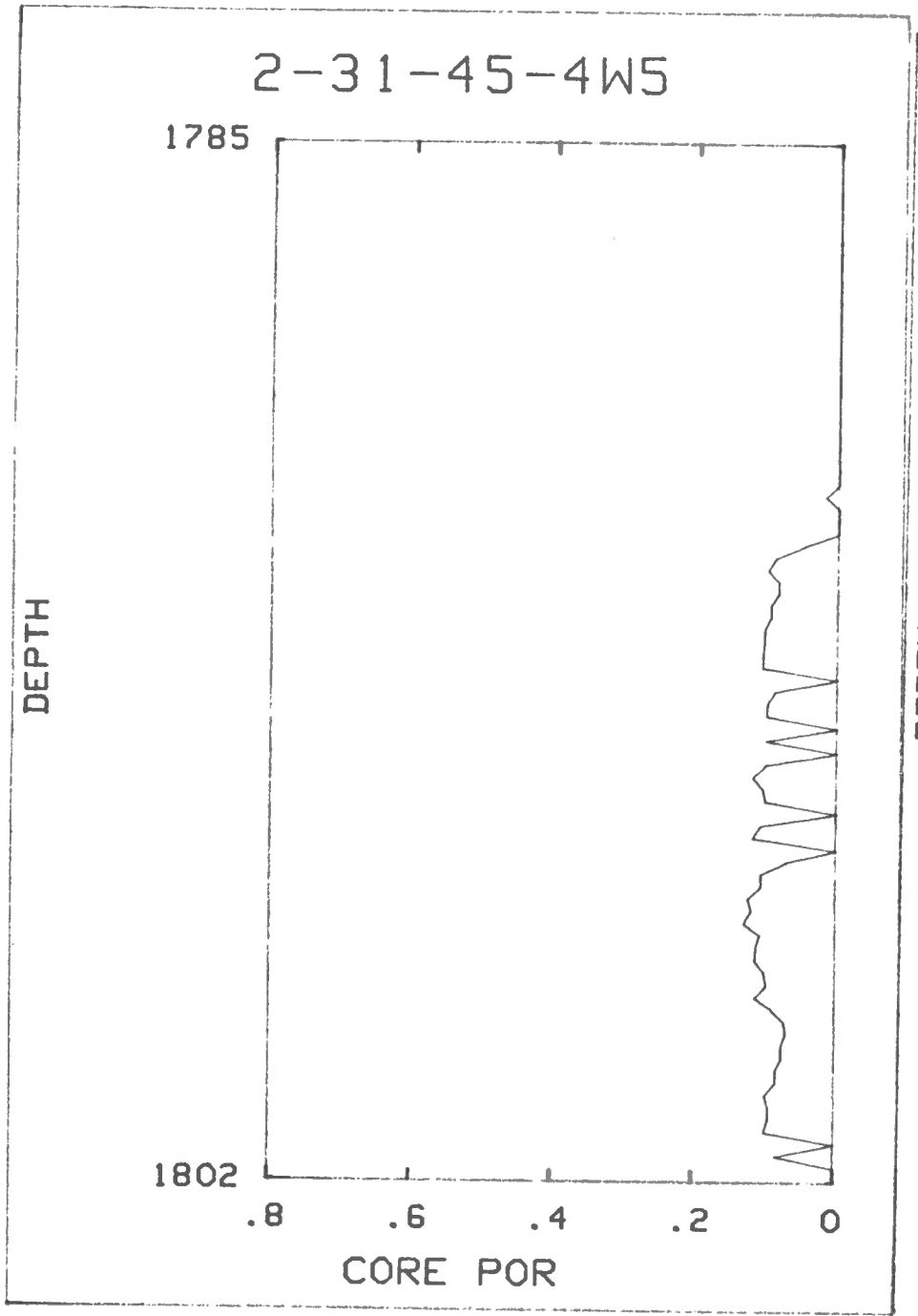

14-20-45-3W5
1760
1777
DEPTH
.8
.6
.4
.2
0
CORE POR

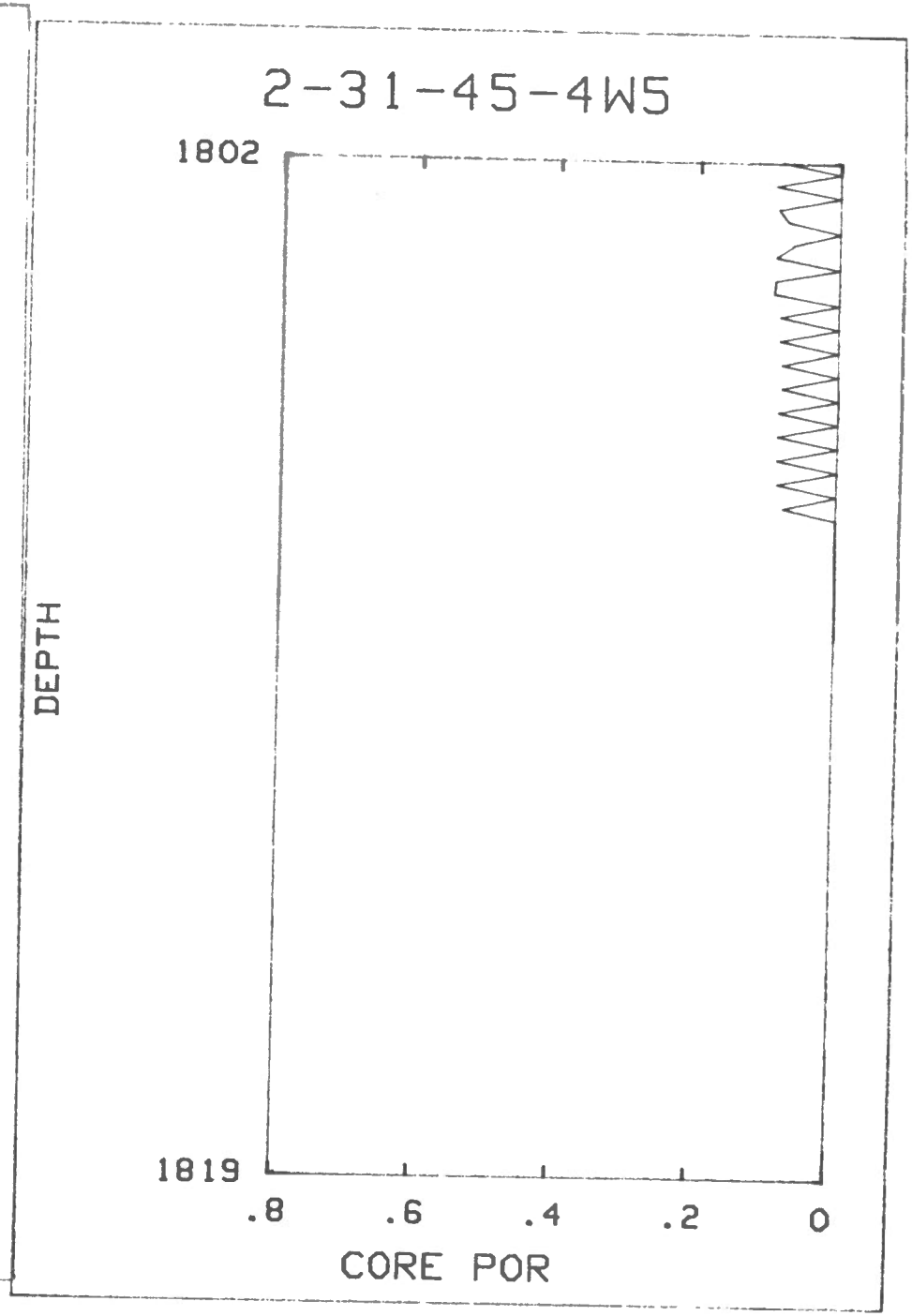
WELL NAME Wesicoast et al Crystal (7 diameter; unslabbed)

LOCATION 2-31-45-3w5

CORE INTERVAL 1790-1799 (Rec 9.0m)
1799-1814 (Rec 15.0m)

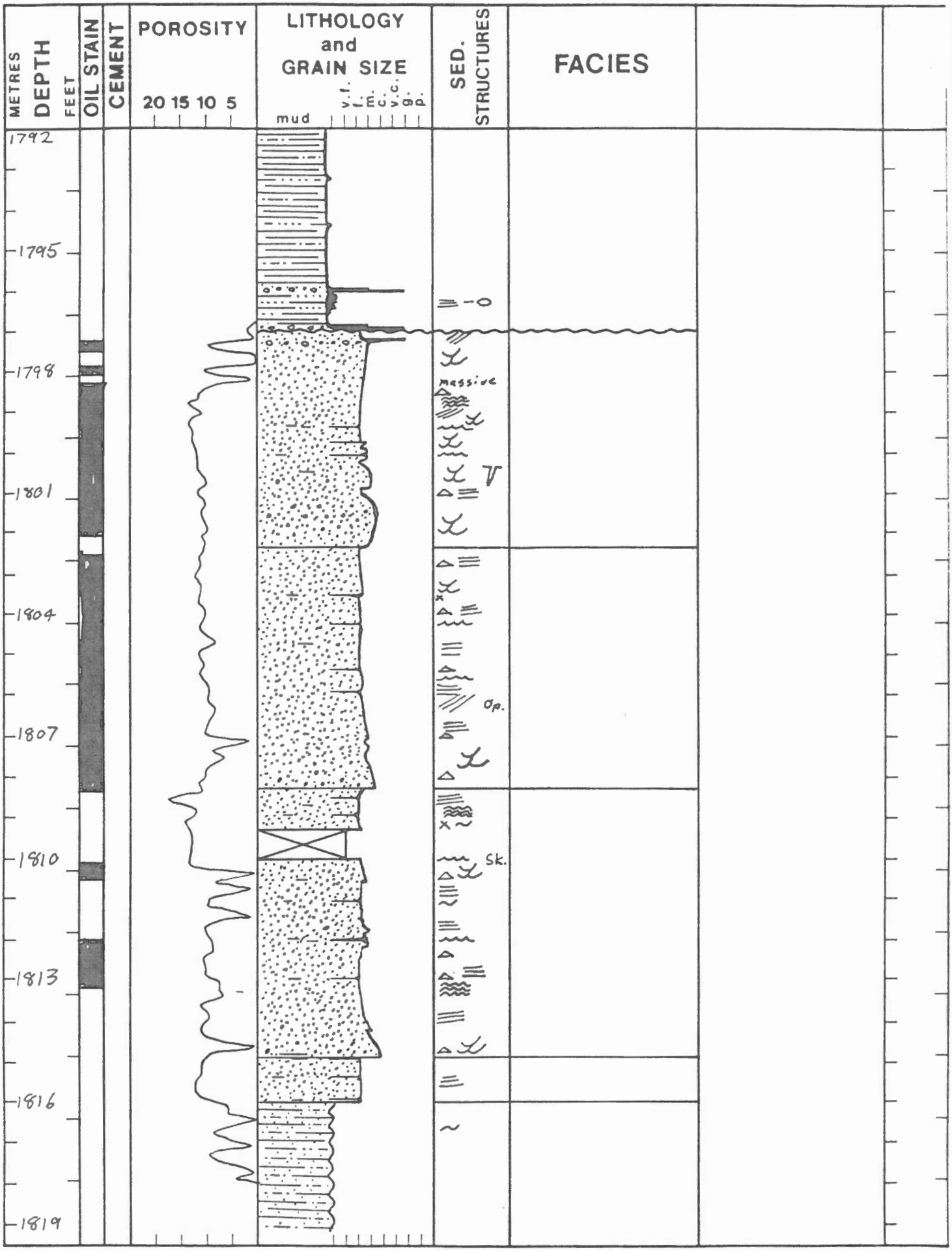


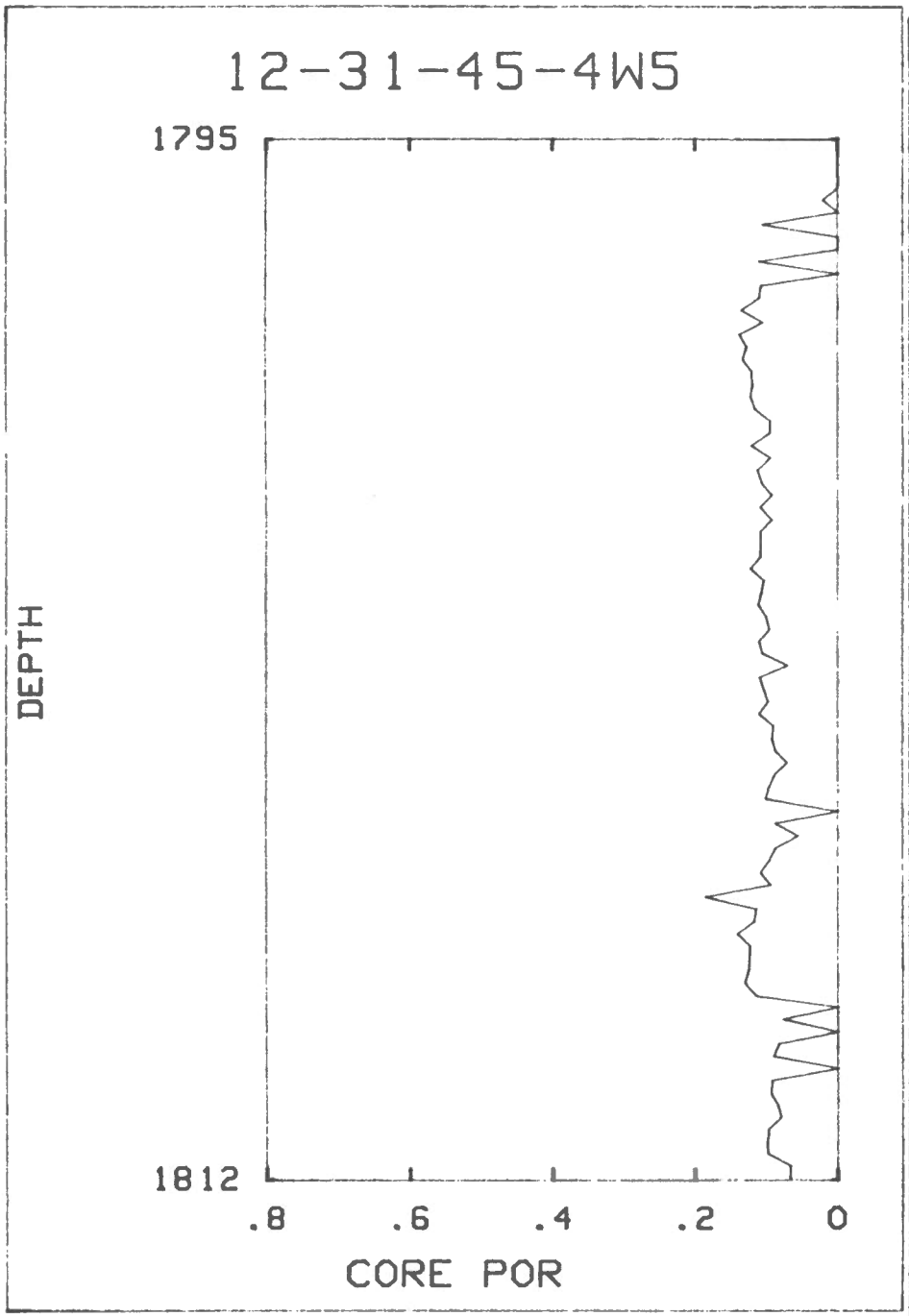

2-31-45-4W5
1785
1802
DEPTH
.8
.6
.4
.2
0
CORE POR

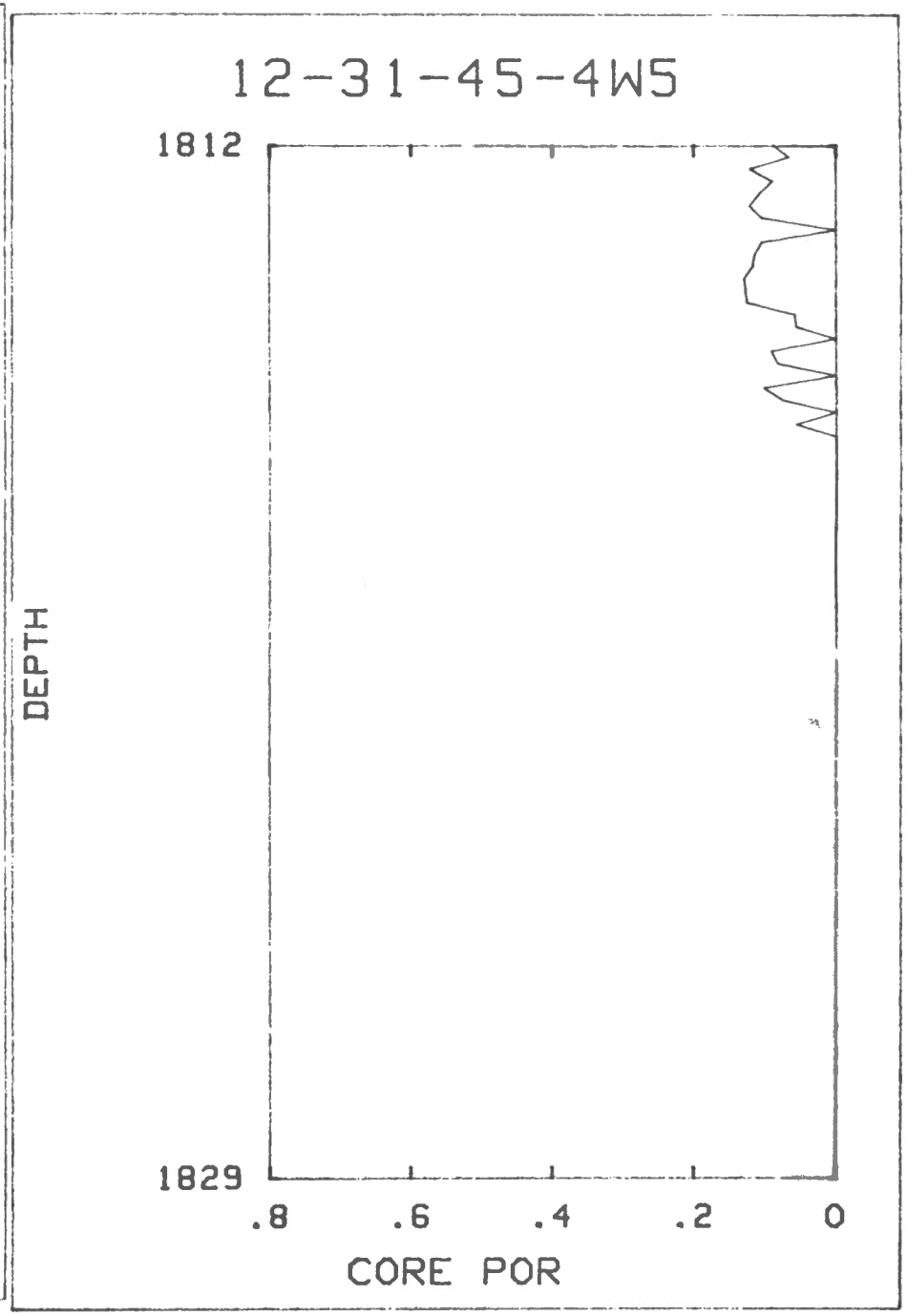

2-31-45-4W5
1802
1819
DEPTH
.8
.6
.4
.2
0
CORE POR

WELL NAME Westcoast et al Crystal (10cm diameter; unslabbed)

LOCATION 12-31-45-3w5 CORE INTERVAL 1792-1810 (Rec 17.25.
1810-1820 (Rec 9.5m)

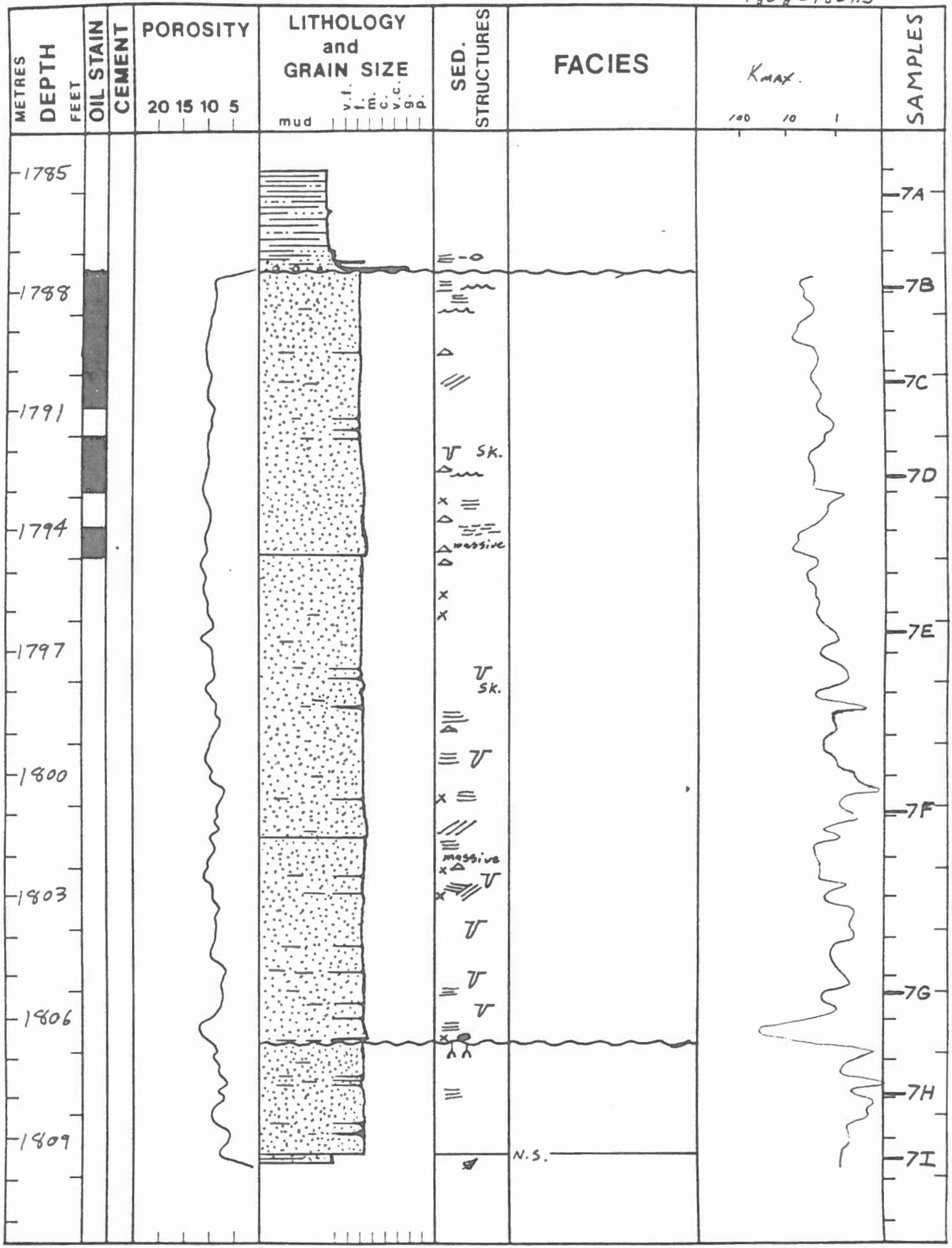


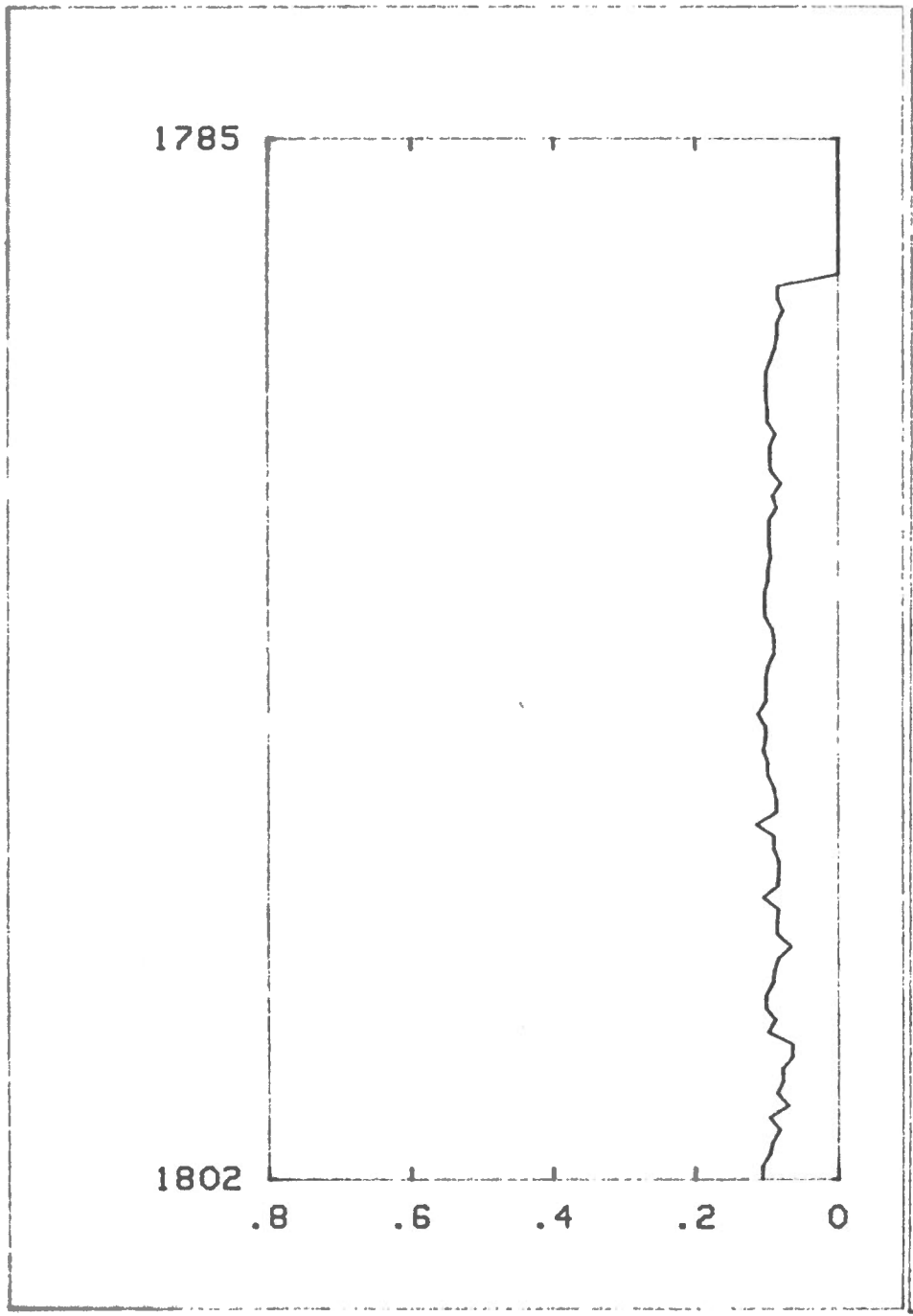

12-31-45-4W5
1795
1812
DEPTH
.8
.6
.4
.2
0
CORE POR

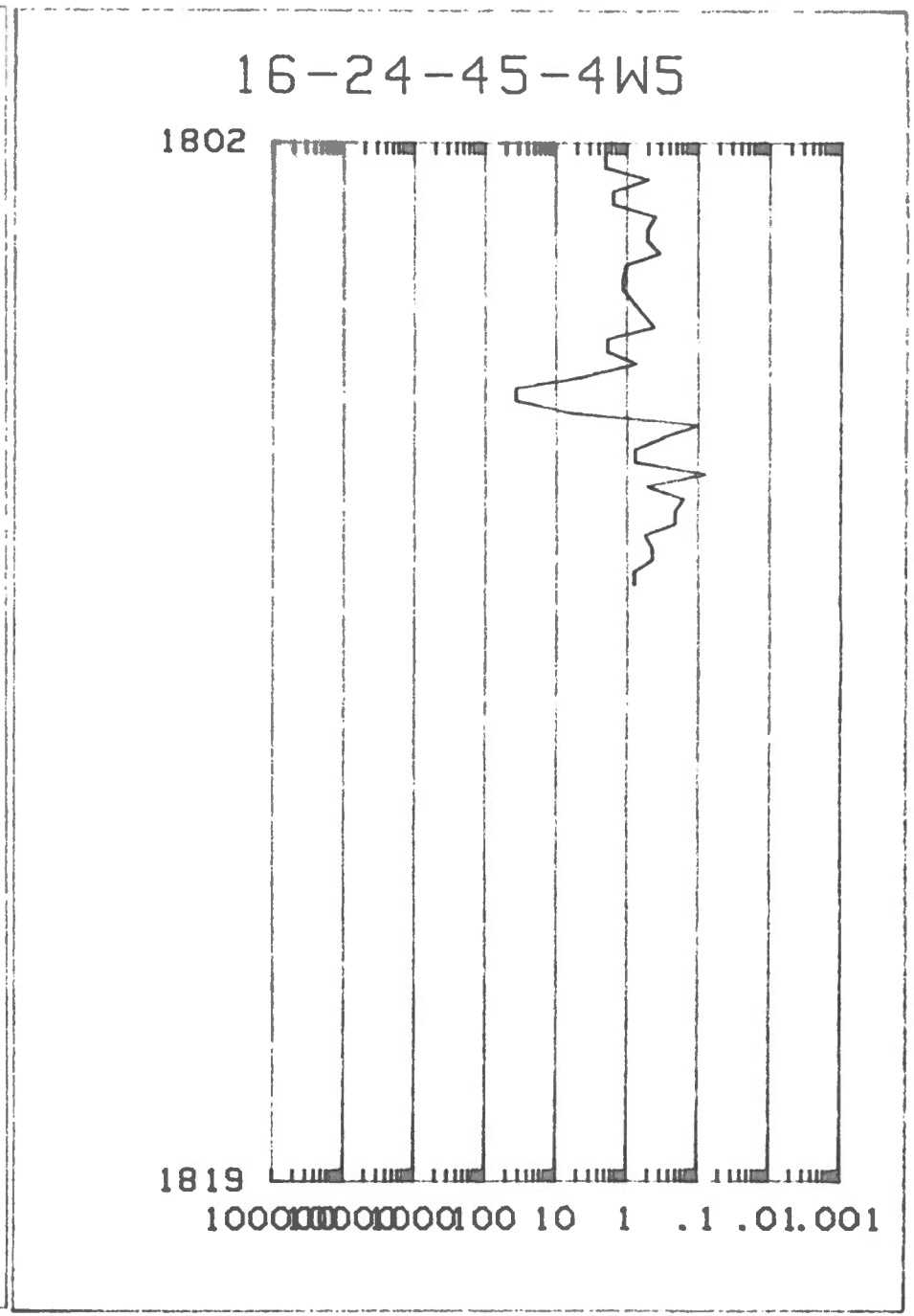

12-31-45-4W5
1812
1829
DEPTH
.8
.6
.4
.2
0
CORE POR

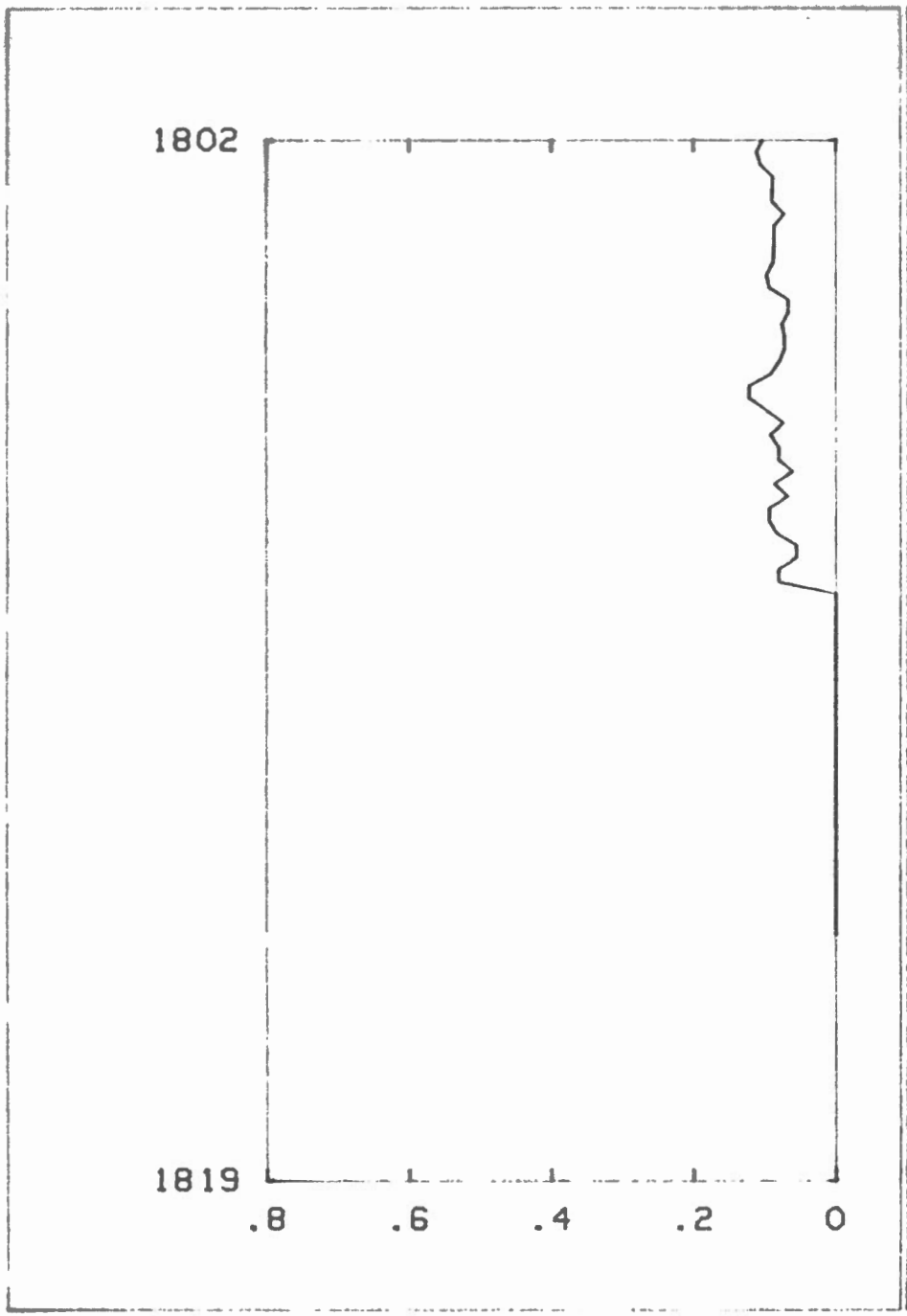
WELL NAME Chiefco et al Crystal (10cm diameter, partially sheared)

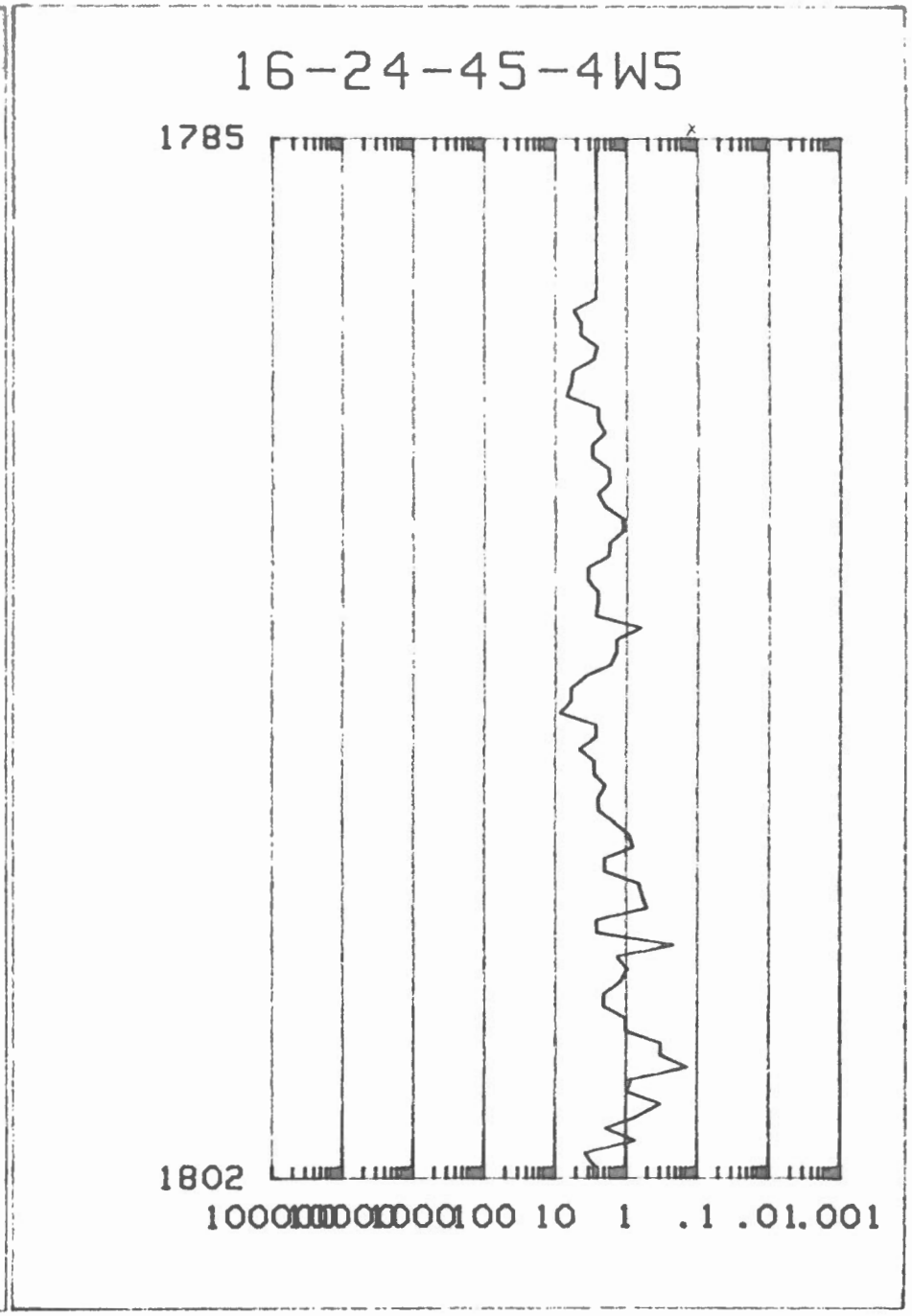
LOCATION 16-24-95-4W5 CORE INTERVAL 1785.5-1790 / 1790-1808 / 1808-1809.5




1785
1802
.8
.6
.4
.2
0

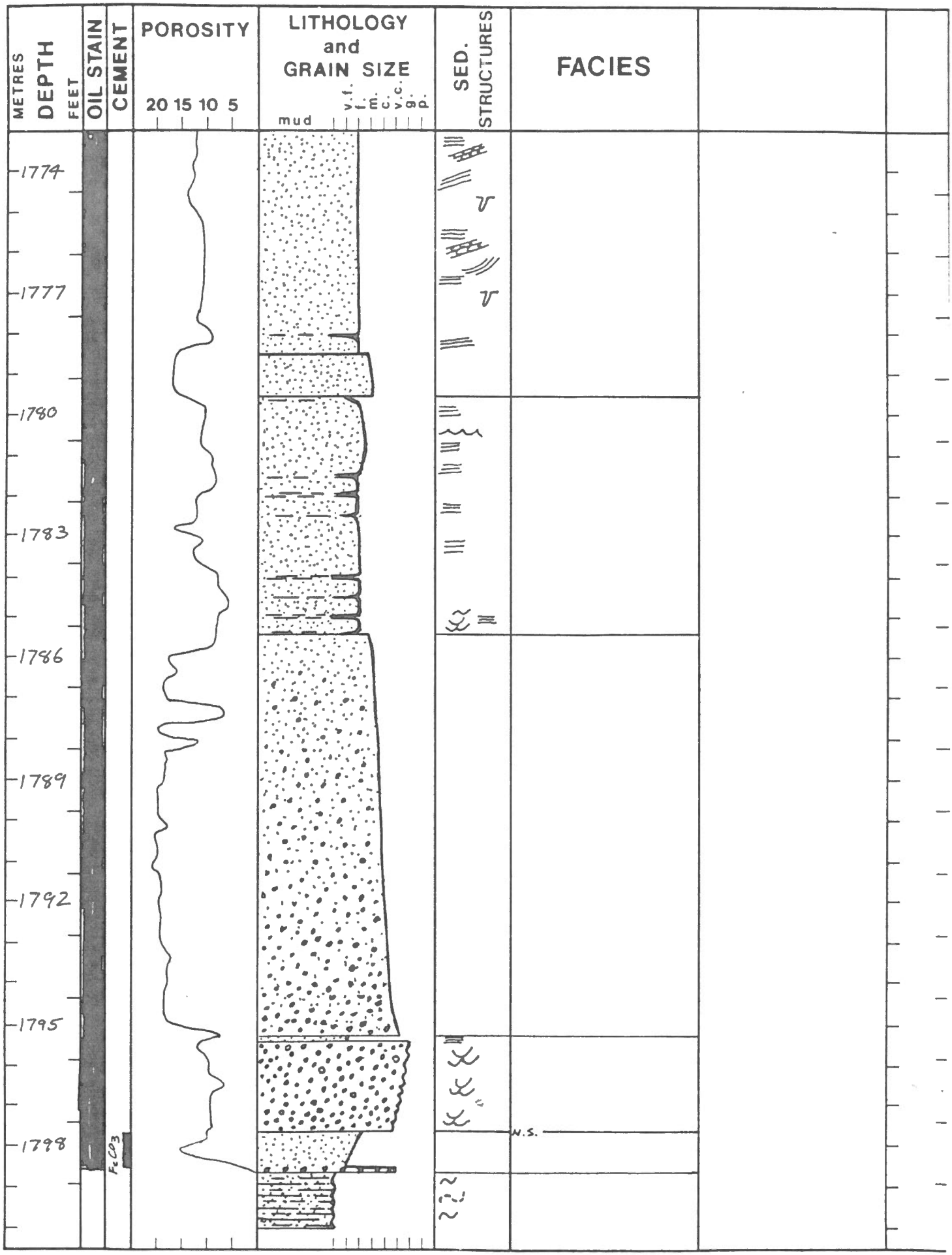

16-24-45-4W5
1802
1819
1000
100
10
1
.1
.01
.001

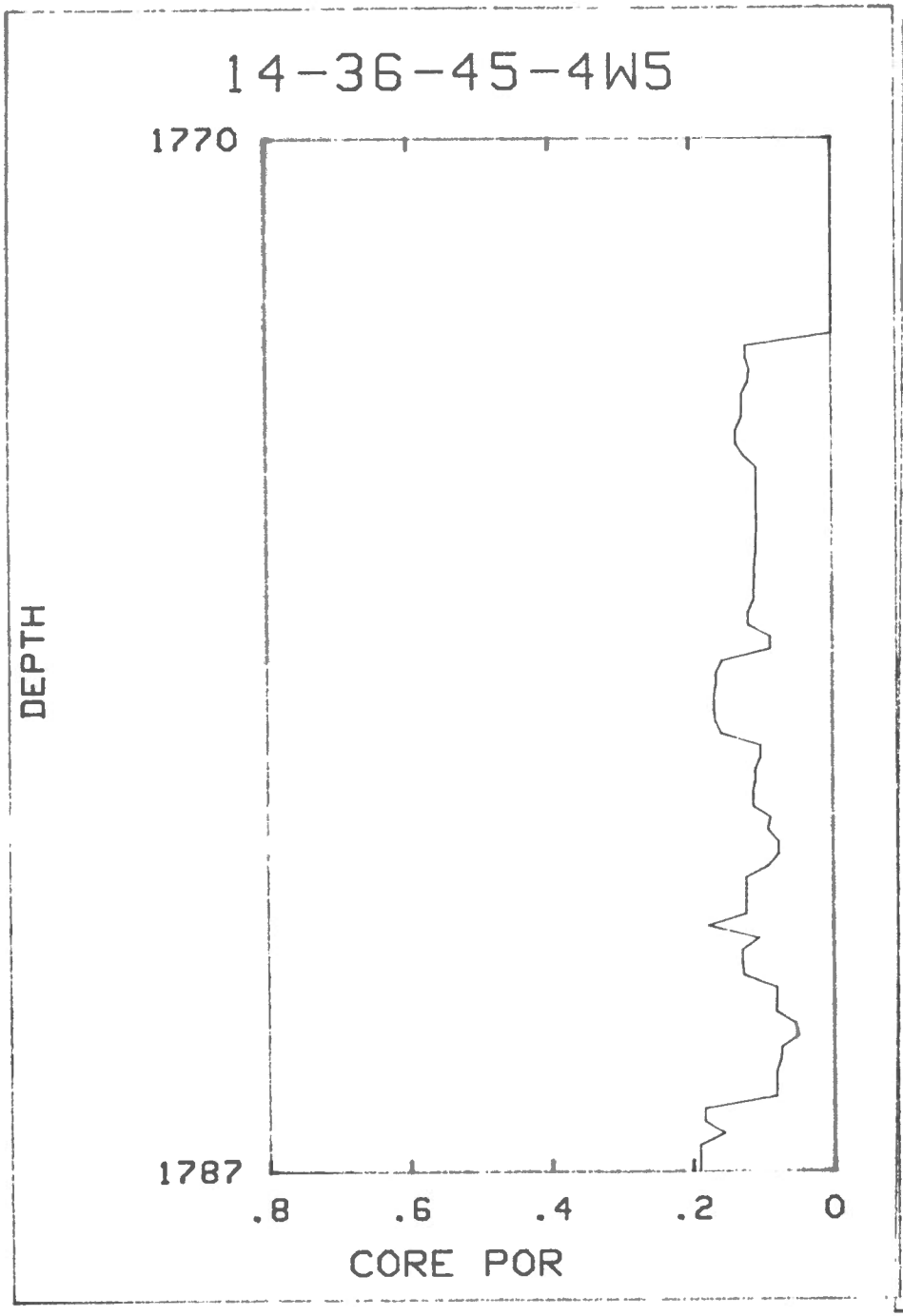

1802
1819
.8
.6
.4
.2
0

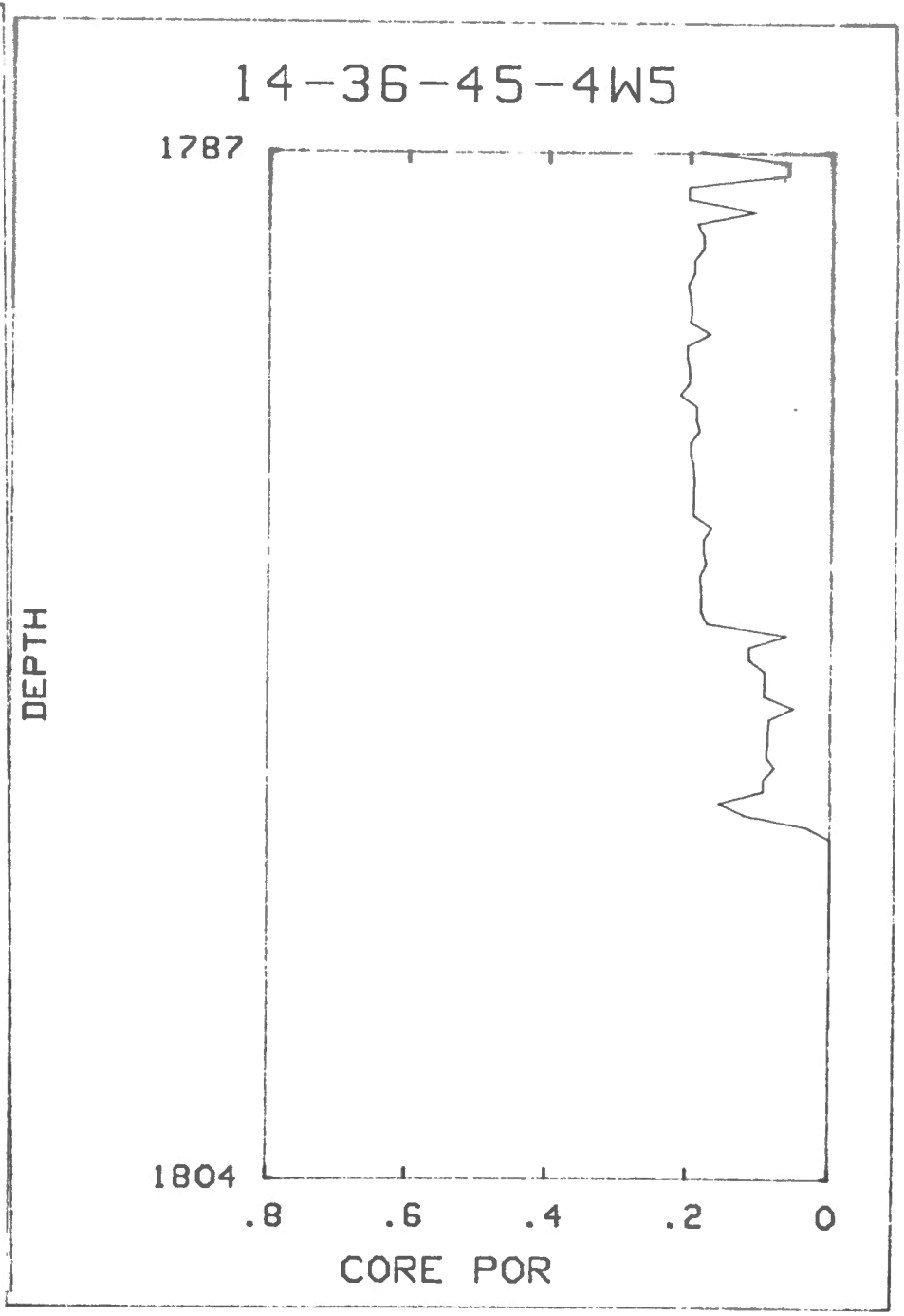

16-24-45-4W5
1785
1802
1000
100
10
1
.1
.01
.001

WELL NAME Petrocan Murphy Crystal

LOCATION 14-36-45-4W5 CORE INTERVAL 1773-1791; 1791-180

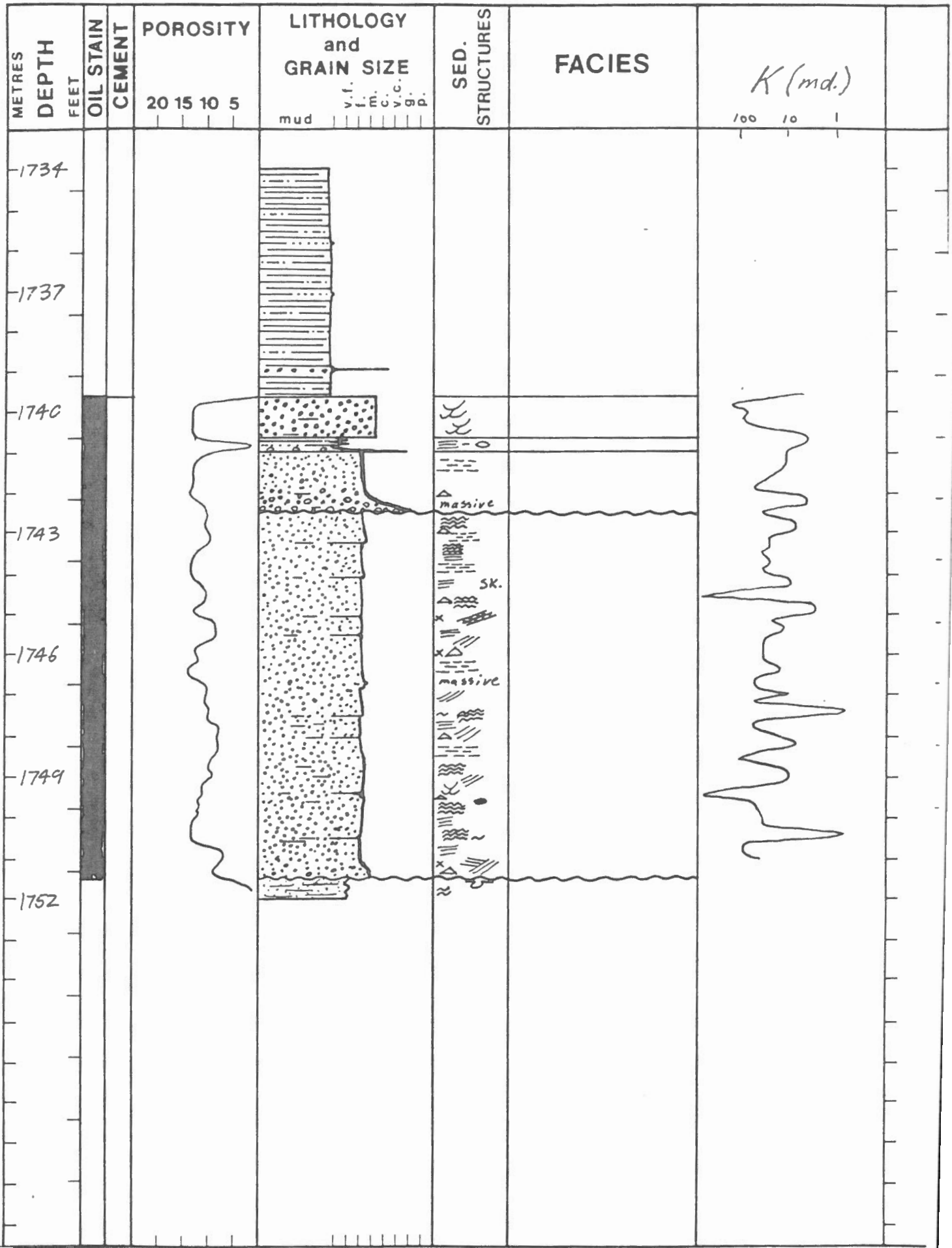


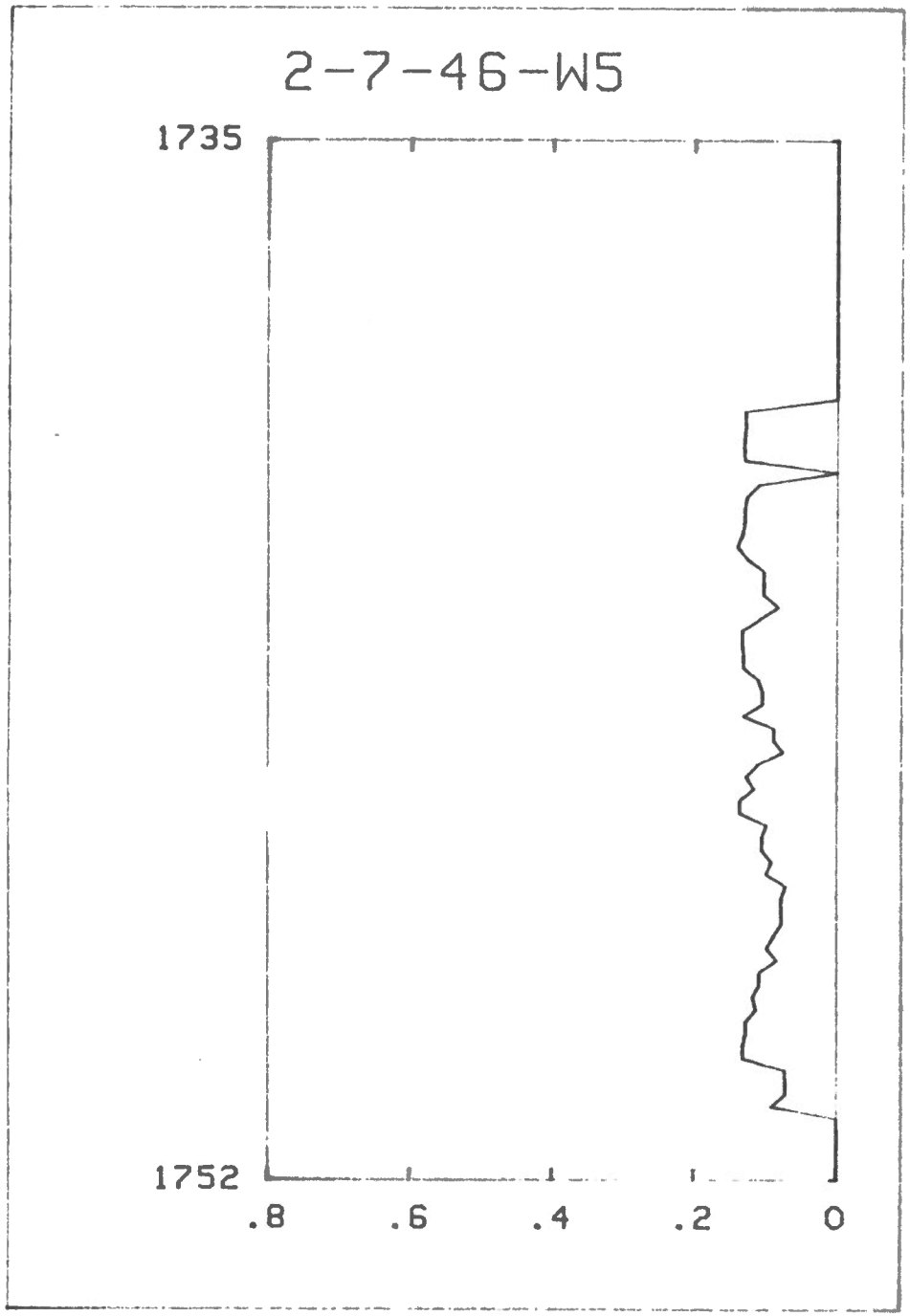

14-36-45-4W5
1770
1787
DEPTH
.8
.6
.4
.2
0
CORE POR

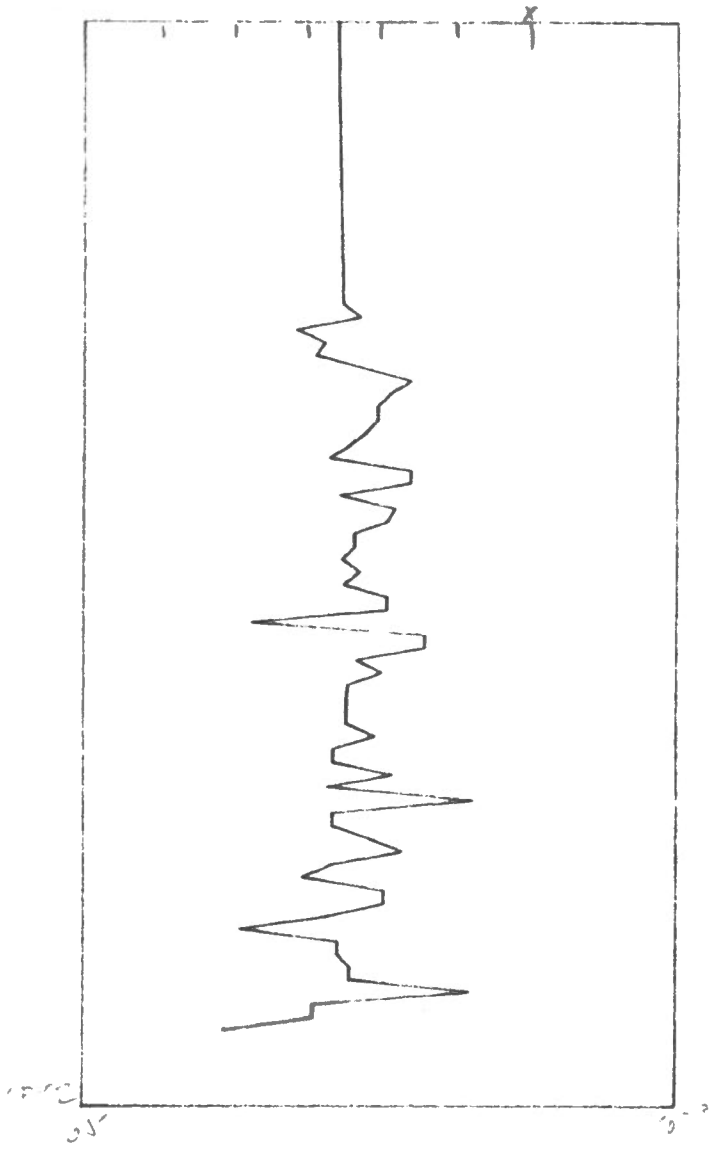

14-36-45-4W5
1787
1804
DEPTH
.8
.6
.4
.2
0
CORE POR

WELL NAME Westcoast et al Crystal (10cm diameter; partially slabbed)

LOCATION 2-7-46-3w5 CORE INTERVAL 1734-1752 (Rec 18

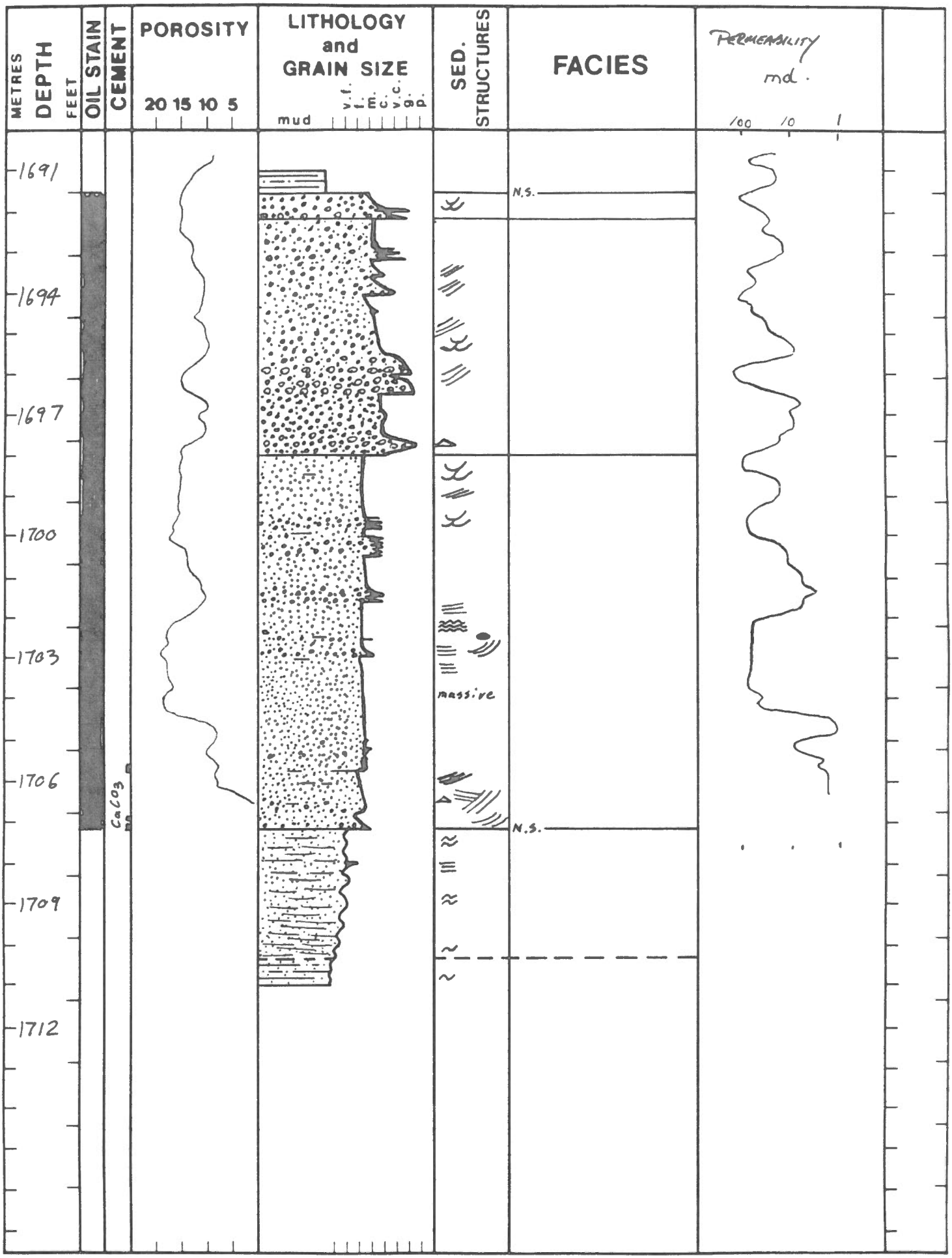


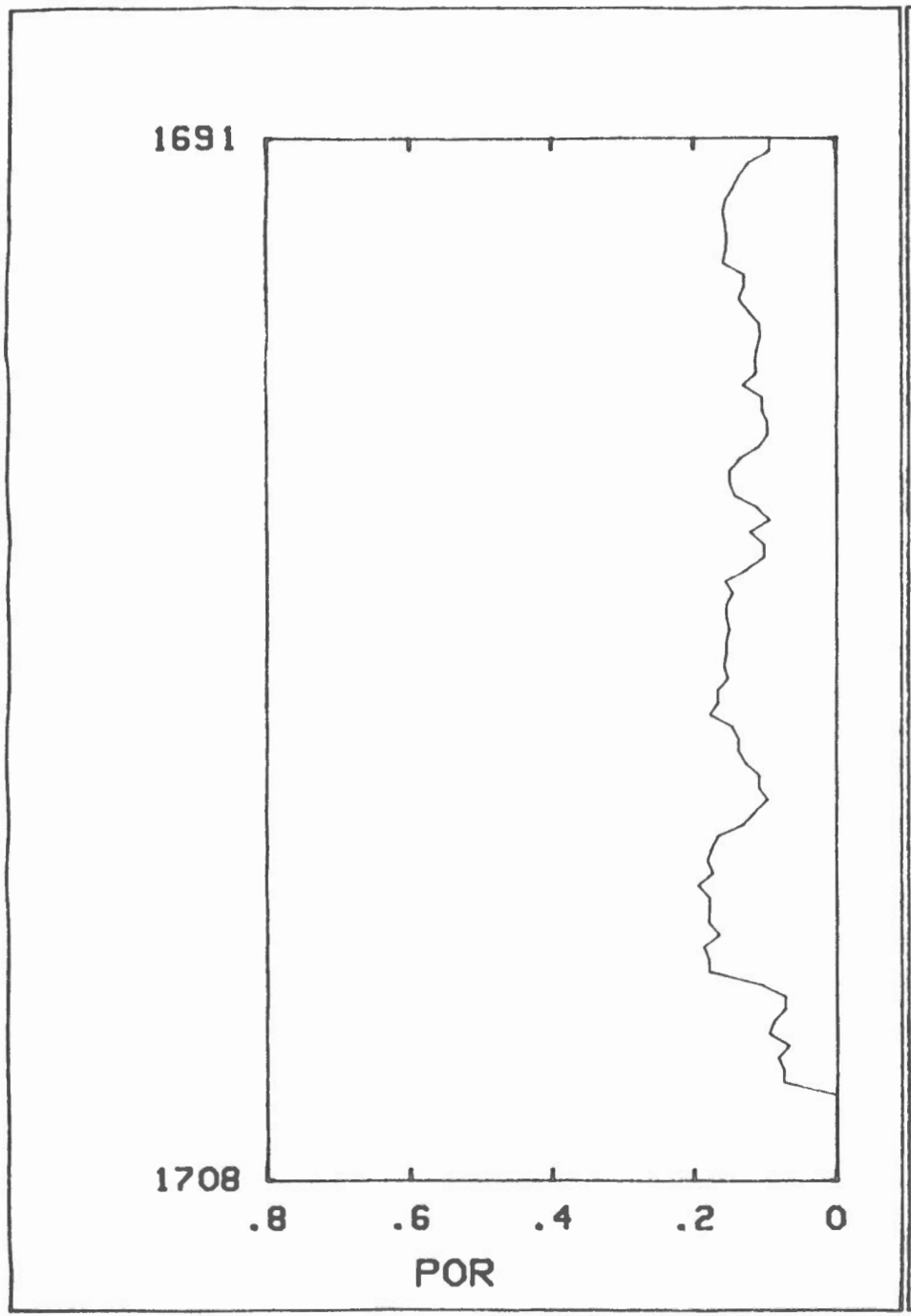

2-7-46-W5
1735
1752
.8
.6
.4
.2
0

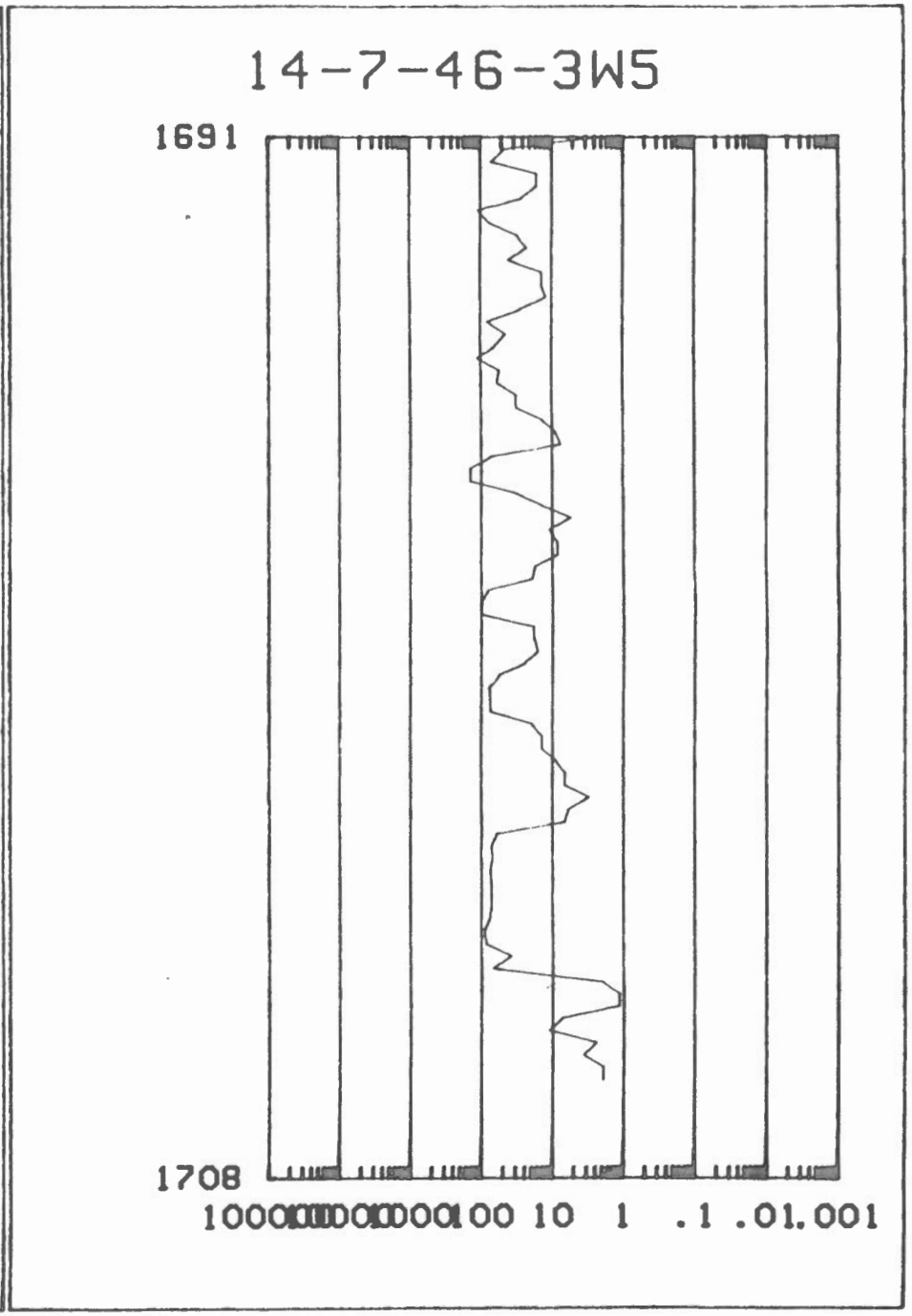


WELL NAME Bluesky et al Crystal (8cm diameter; partially slabbed)

LOCATION 14-7-46-3W5 CORE INTERVAL 1691-1696 (Rec 5m) 1696-1711 (Rec 15m)

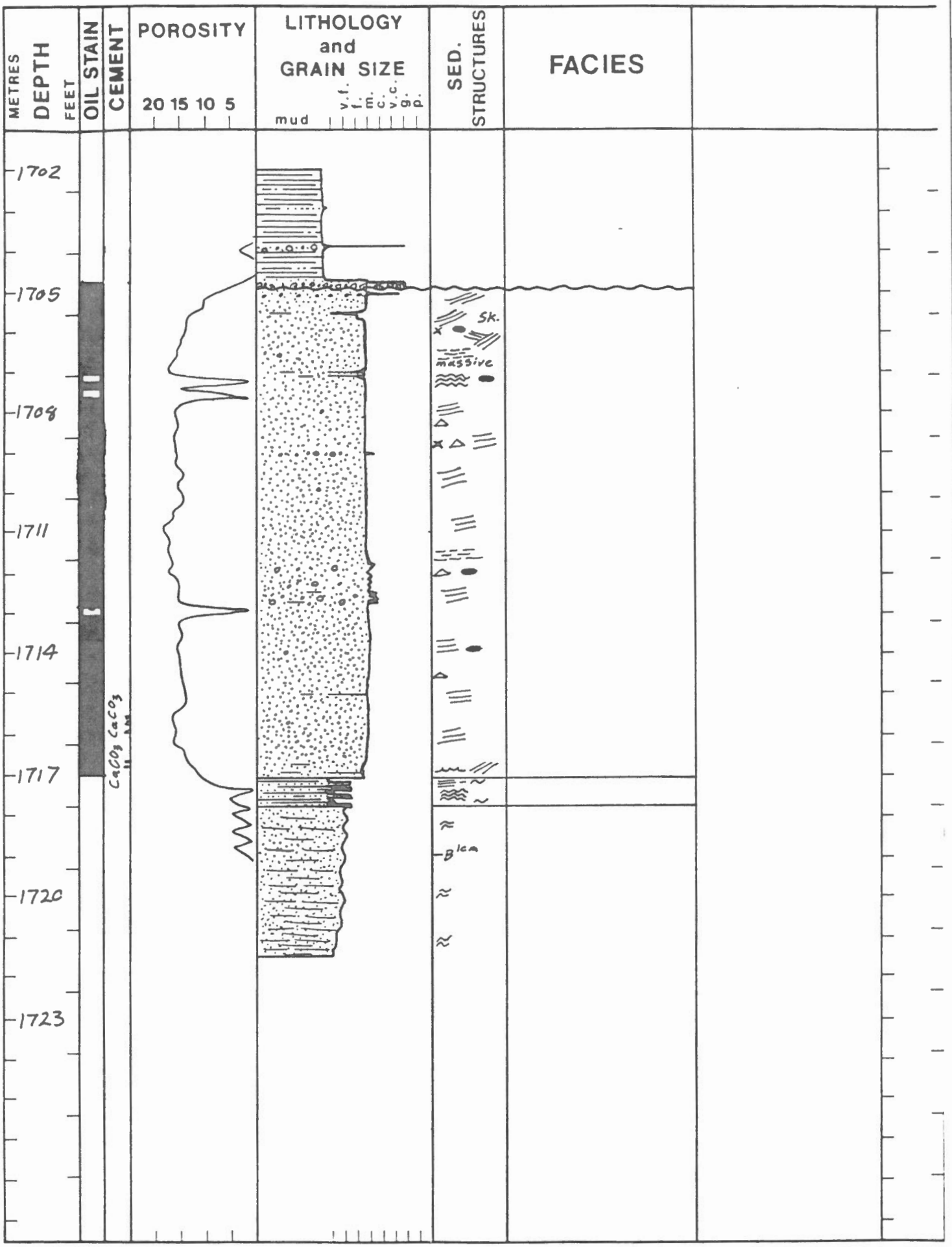


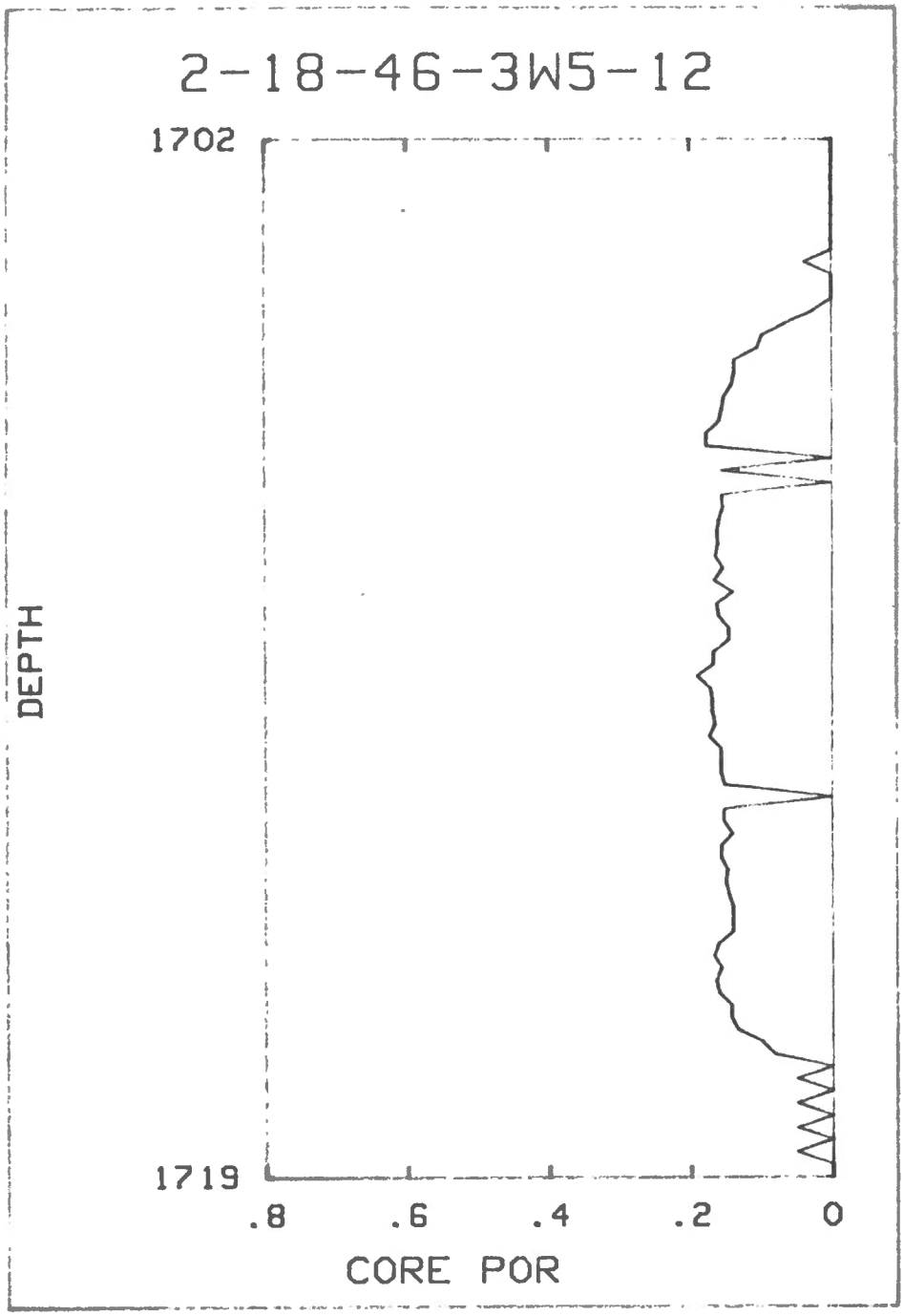

1691
1708
.8
.6
.4
.2
0
POR


14-7-46-3W5
1691
1708
100
10
1
.1
.01
.001

WELL NAME Westcoast et al Crystal (10cm diameter; unslabbed)

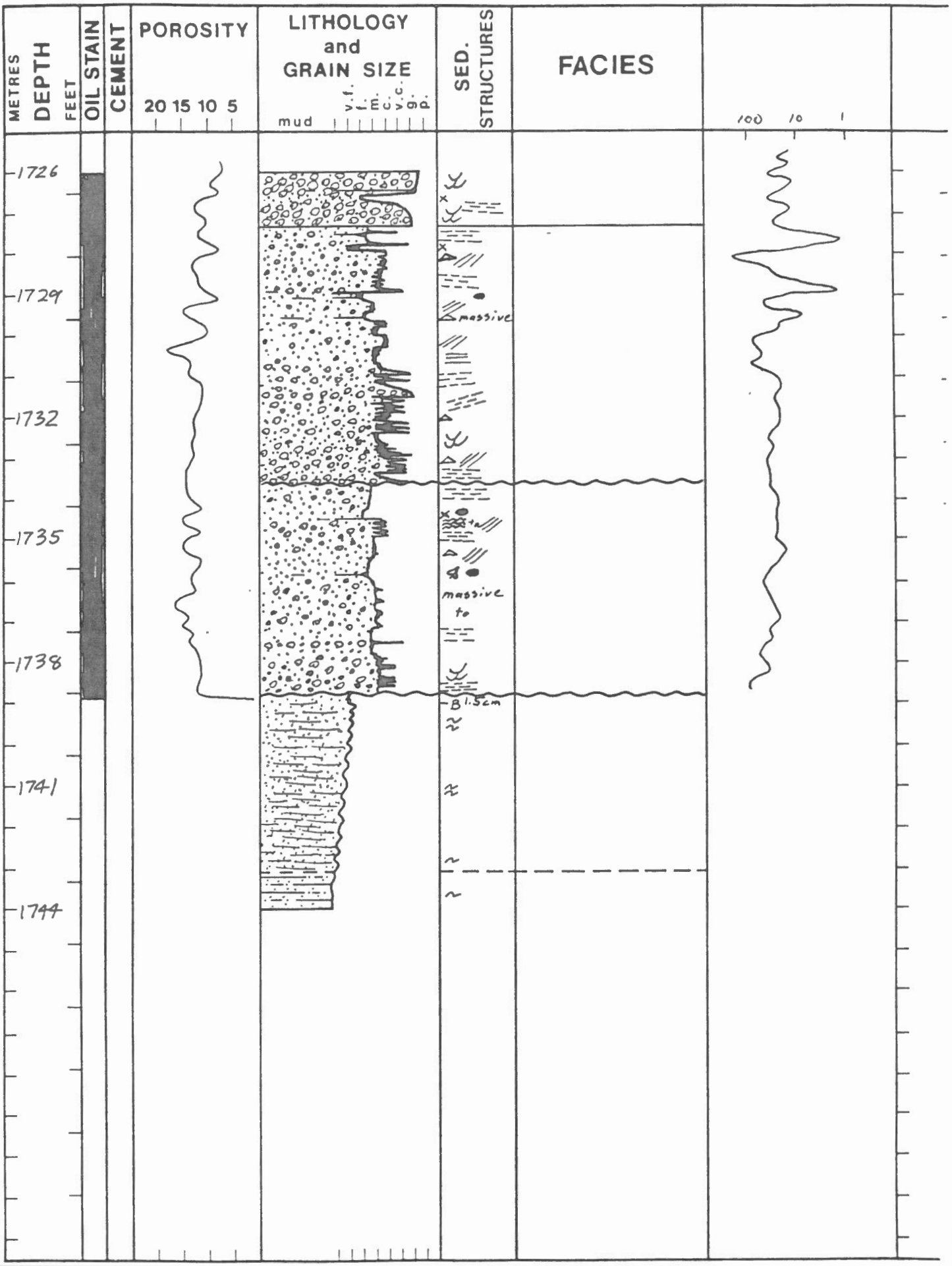
LOCATION 2-18-46-3W5 CORE INTERVAL 1702-1705 (Rec 3.0m)
1705-1721.5 (Rec 16.5m)

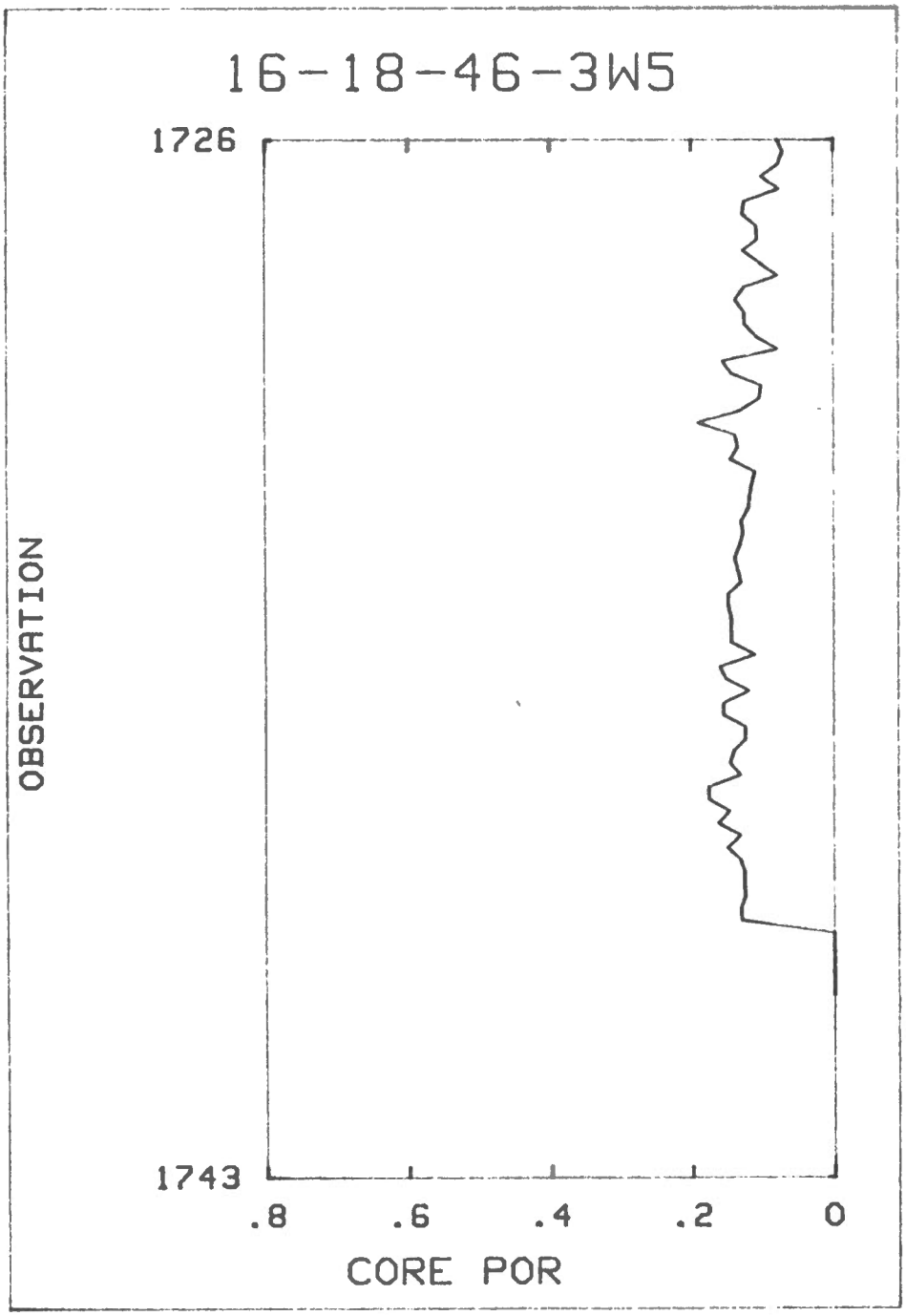


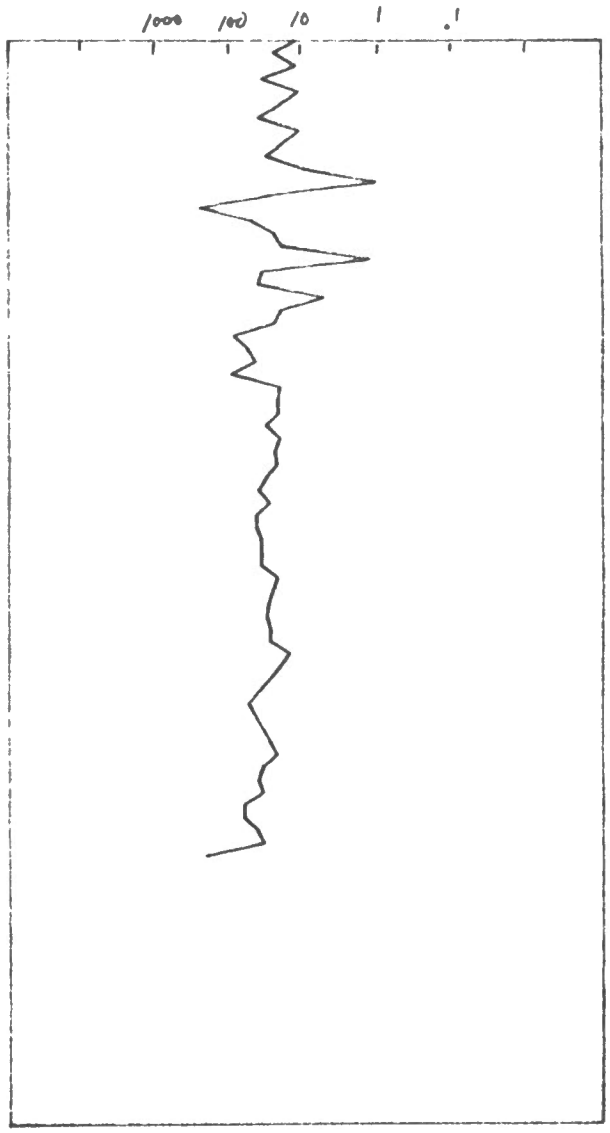

2-18-46-3W5-12
1702
DEPTH
1719
.8
.6
.4
.2
0
CORE POR

WELL NAME Westcoast et al Crystal (10cm diameter; partially slabbed)

LOCATION 16-18-46-3W5 CORE INTERVAL 1726-1744 (Rec 18m

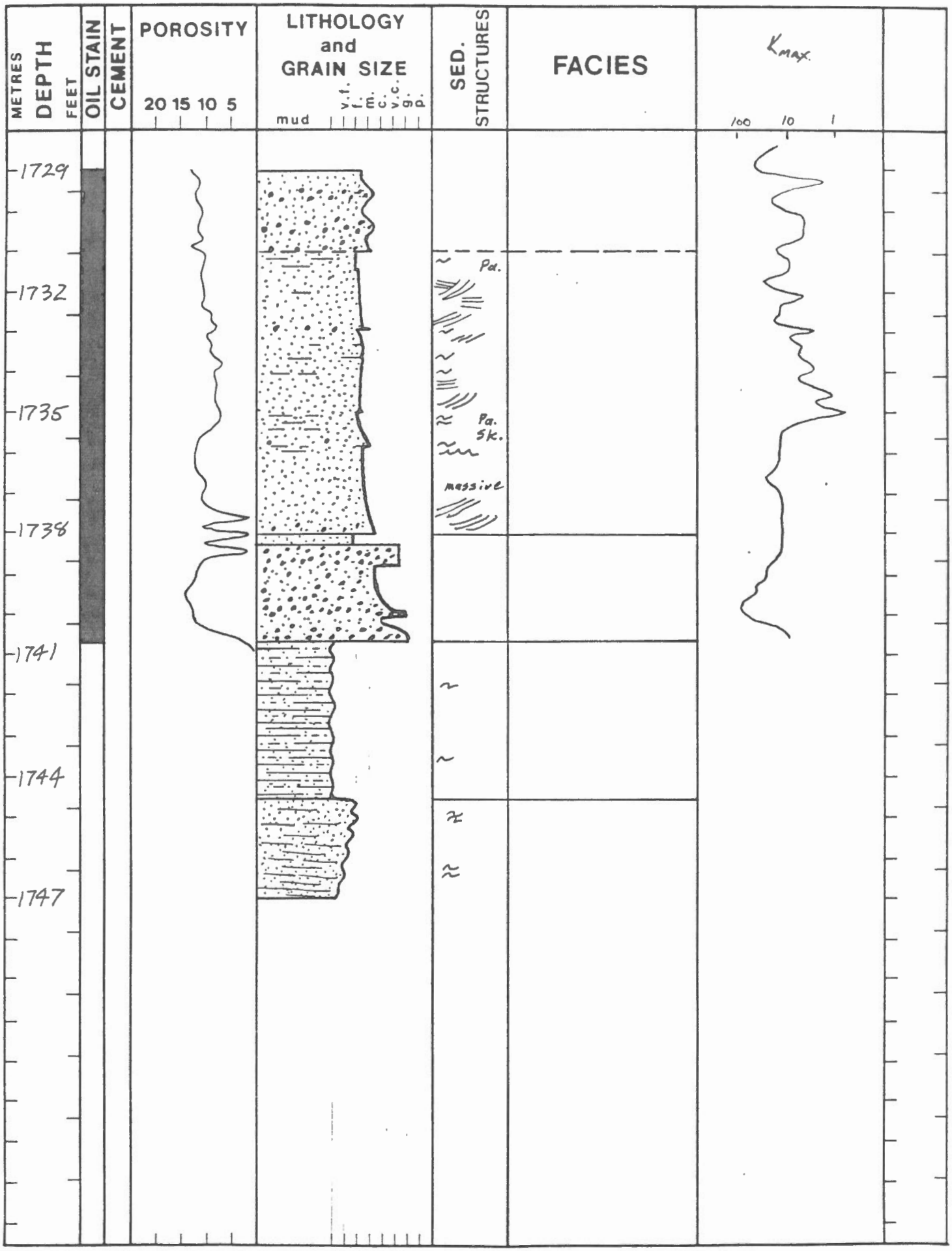


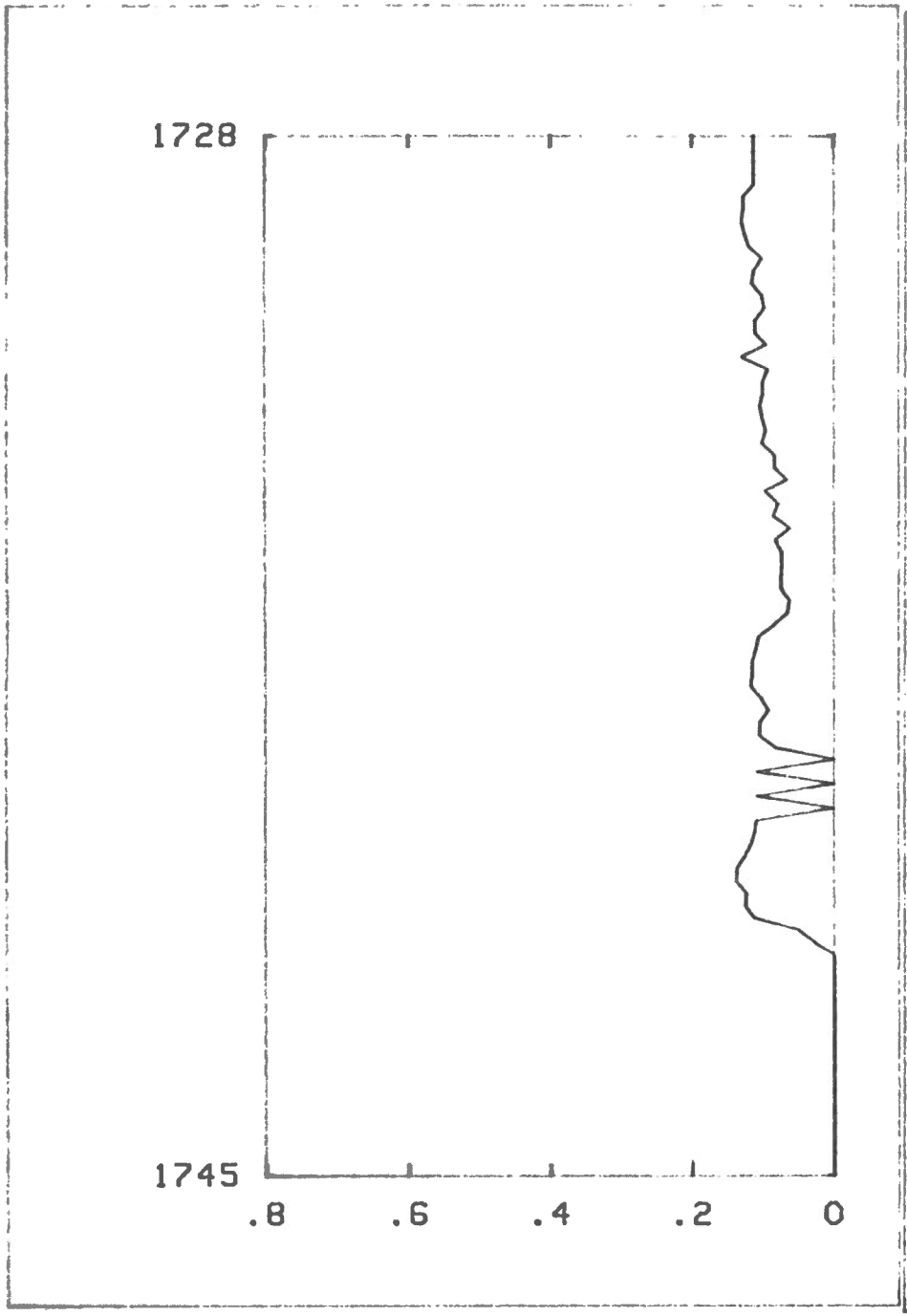

16-18-46-3W5
1726
1743
OBSERVATION
.8
.6
.4
.2
0
CORE POR

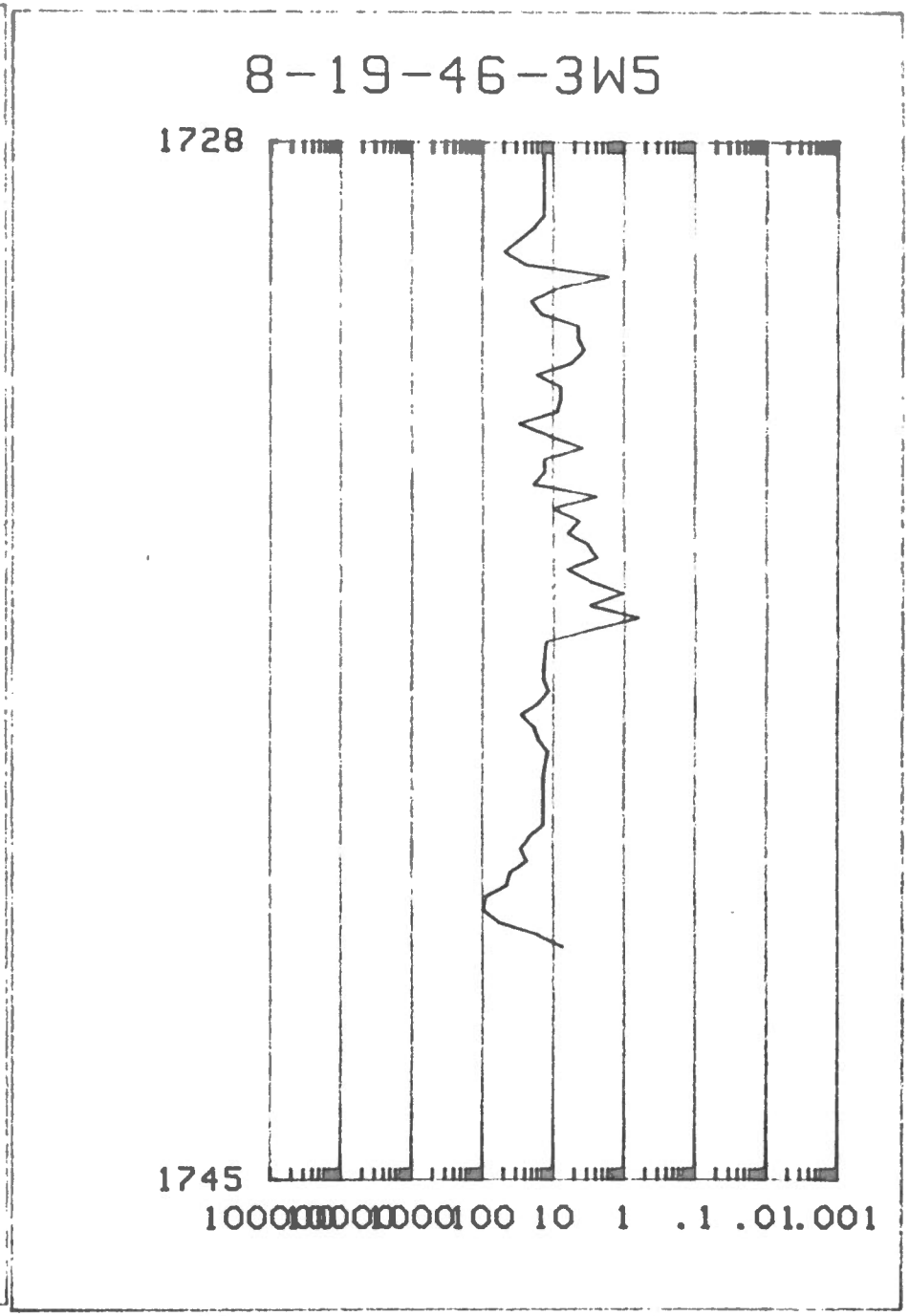

1000
100
10
1
.1

WELL NAME Westcoast OIL Crystal

LOCATION 8-19-46-3W5 CORE INTERVAL 1729-1747

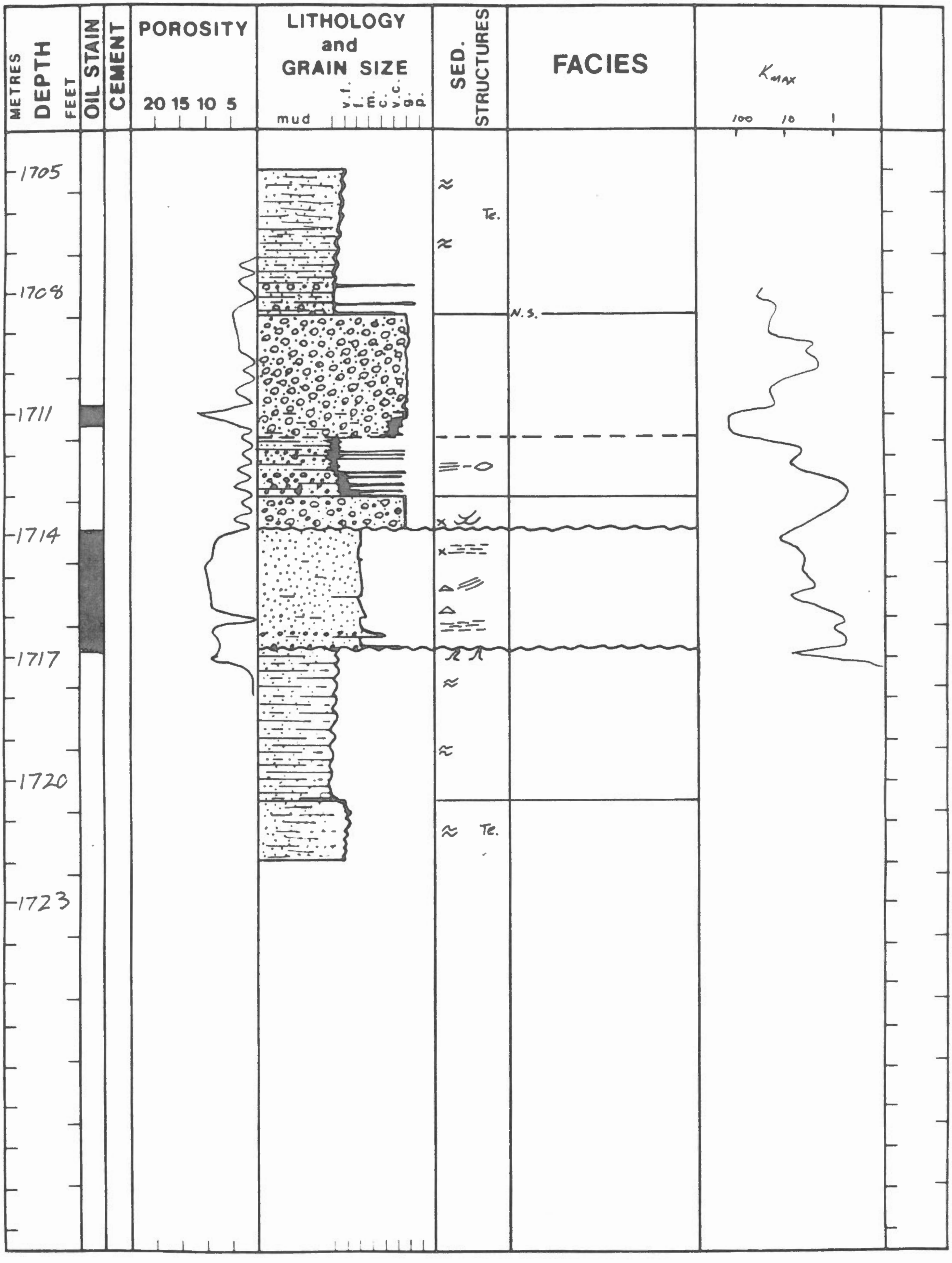


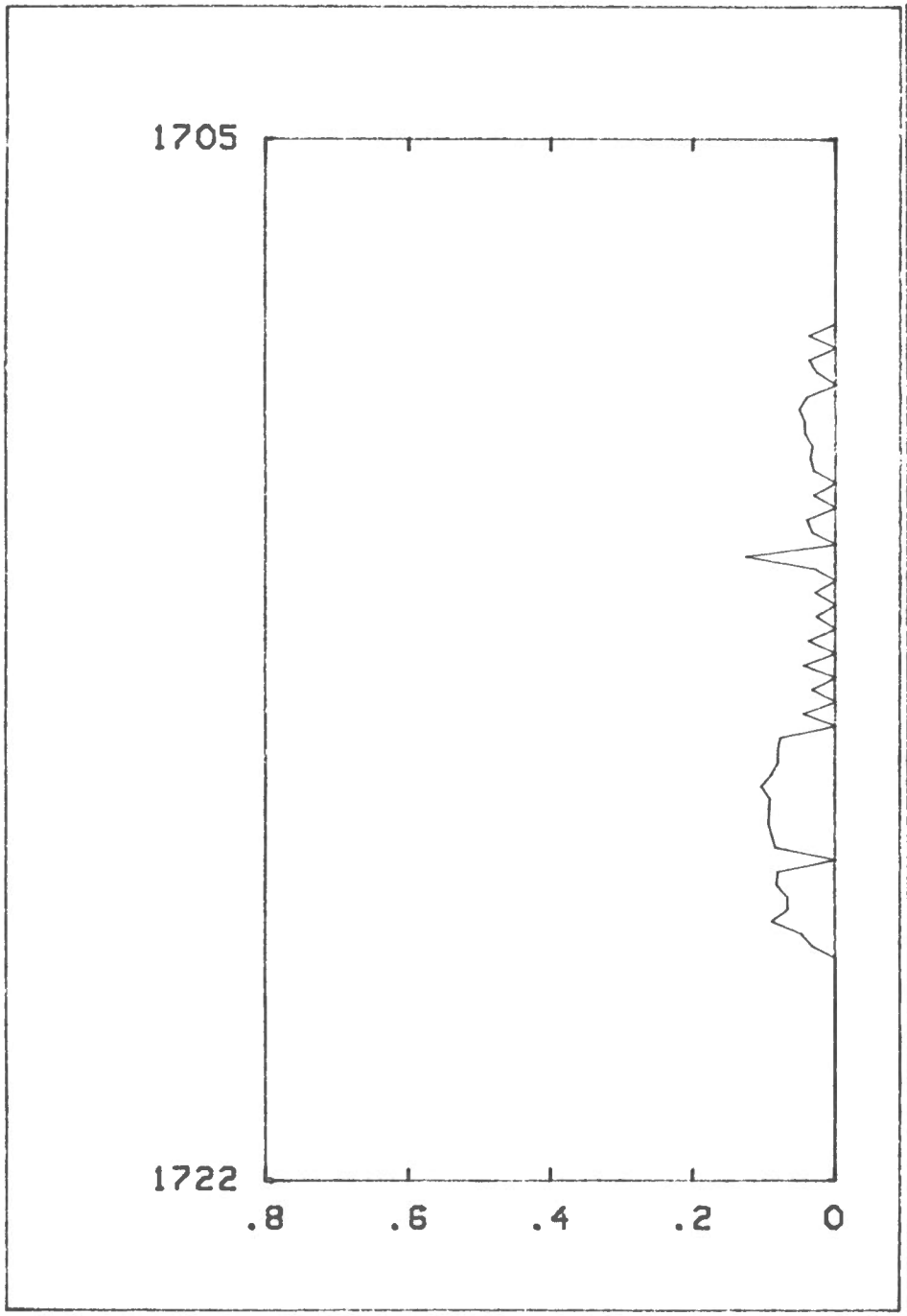

1728
1745
.8
.6
.4
.2
0

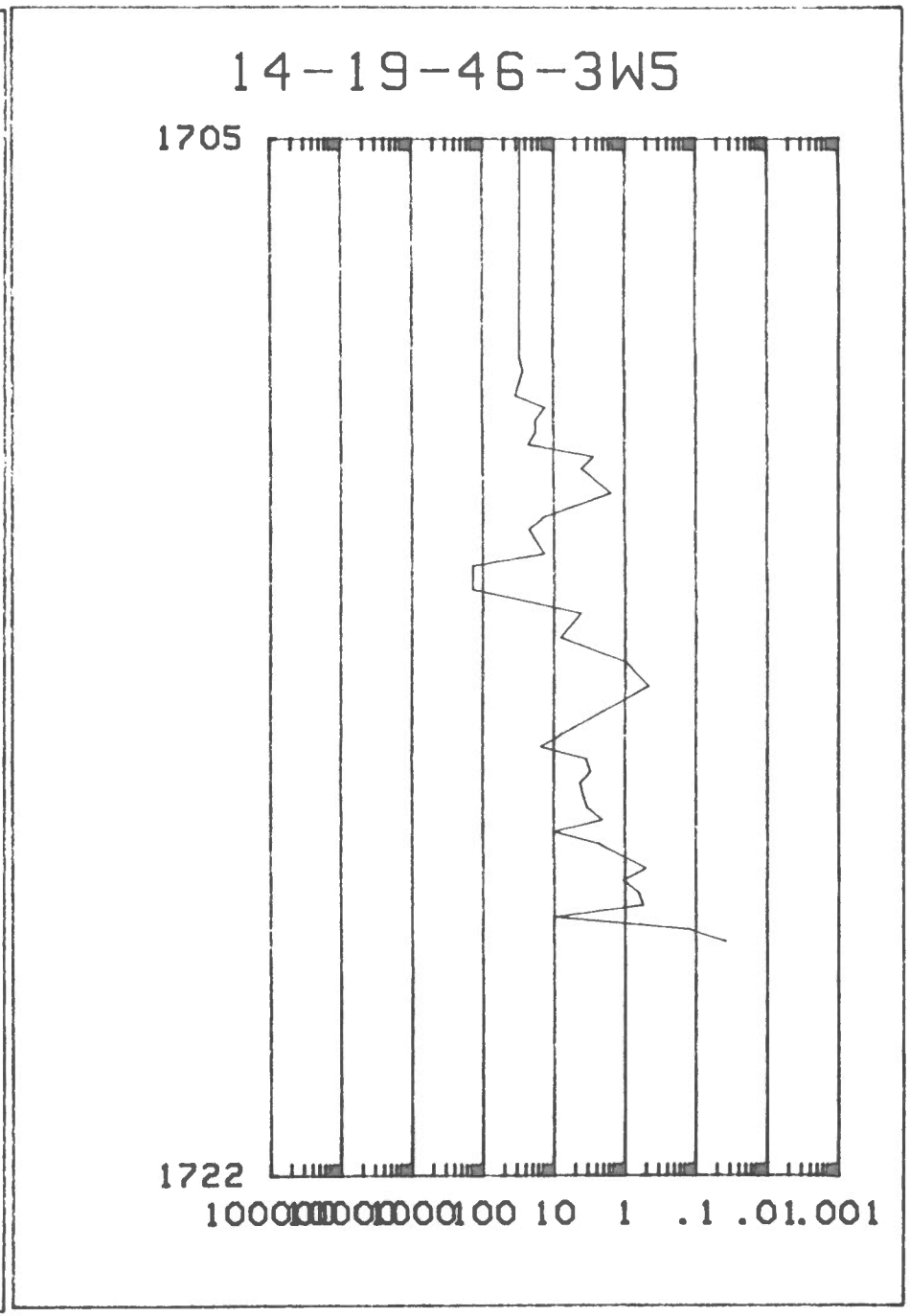

8-19-46-3W5
1728
1745
100
10
1
.1
.01
.001

WELL NAME *West Coast et al Crystal [illegible]*

LOCATION *14-19-46-3W5* CORE INTERVAL *1705-1721.9 (Rec 16.9*

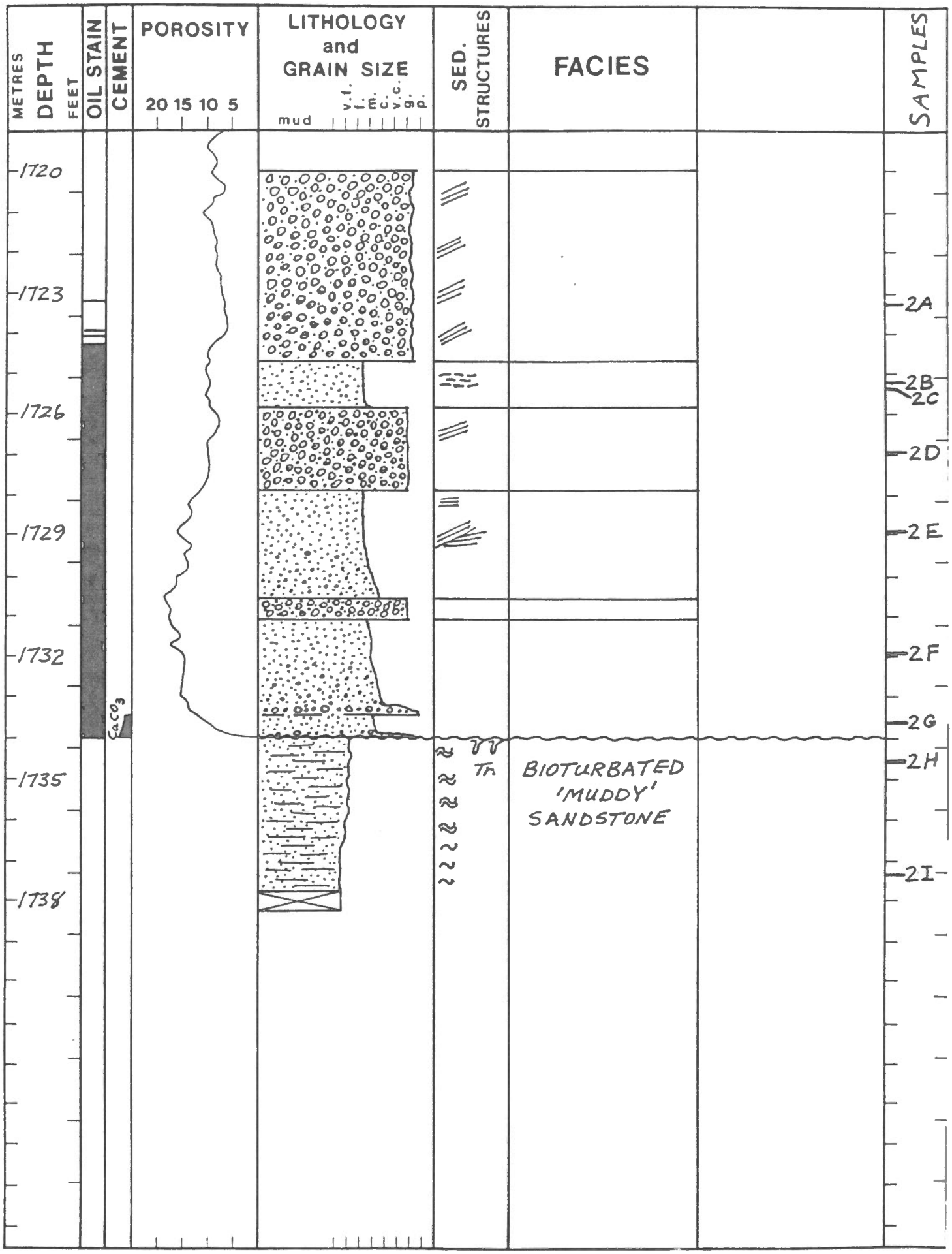


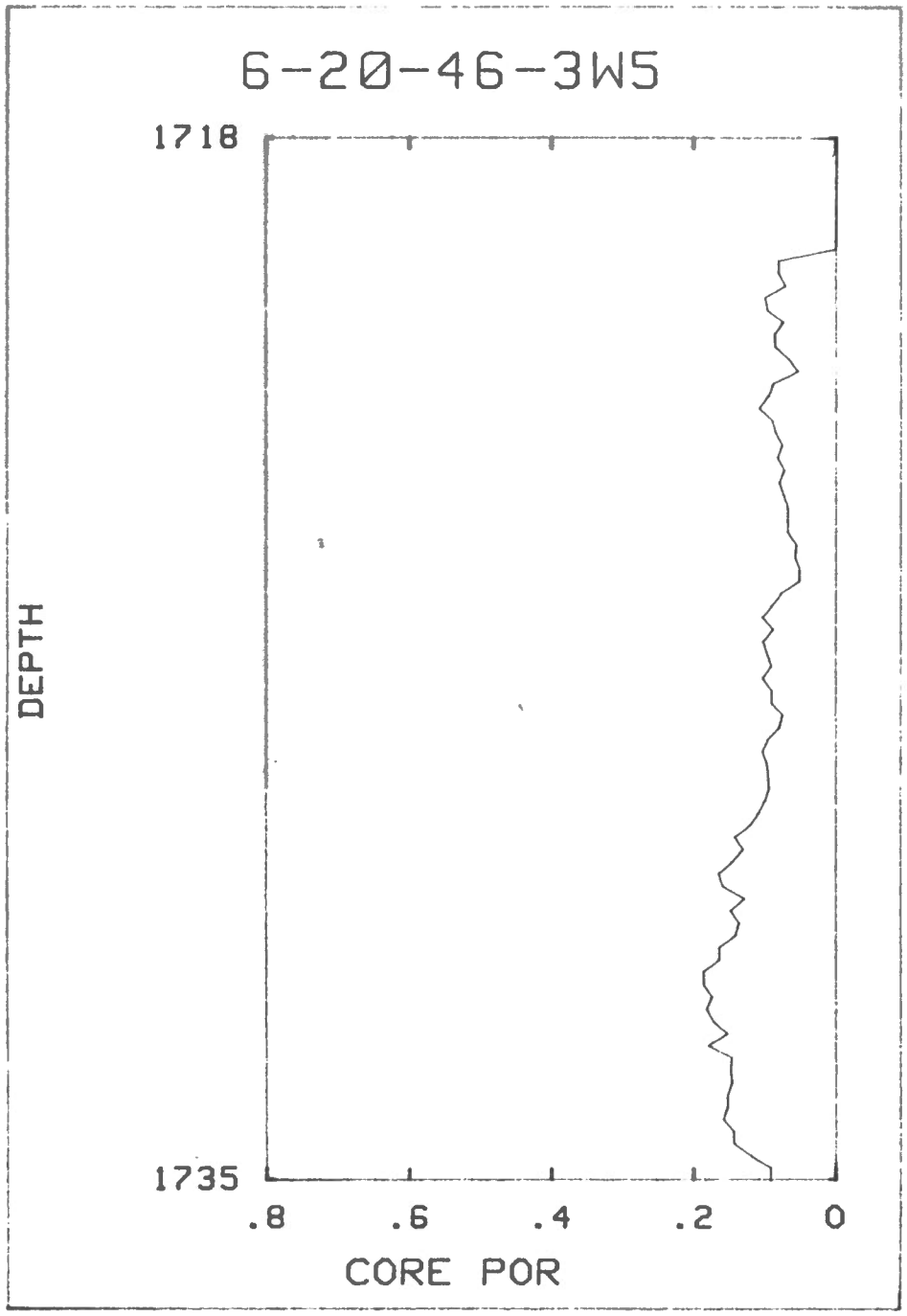

1705
1722
.8
.6
.4
.2
0


14-19-46-3W5
1705
1722
100
10
1
.1
.01
.001

WELL NAME Bumper et al Crystal (10cm diameter, unslabbed)

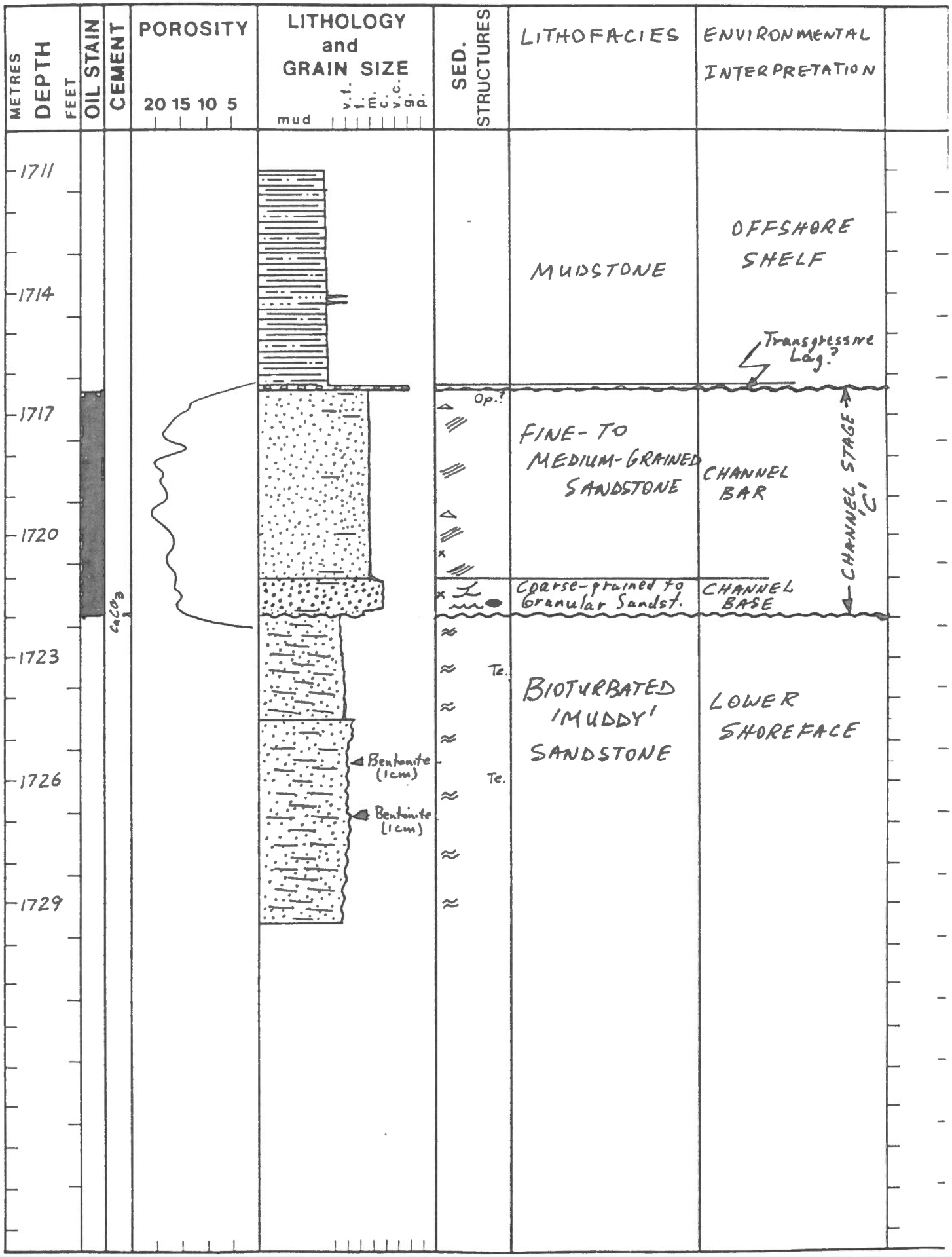
LOCATION 6-20-46-3 w5 CORE INTERVAL 1720-1738.25 (Rec. 17)

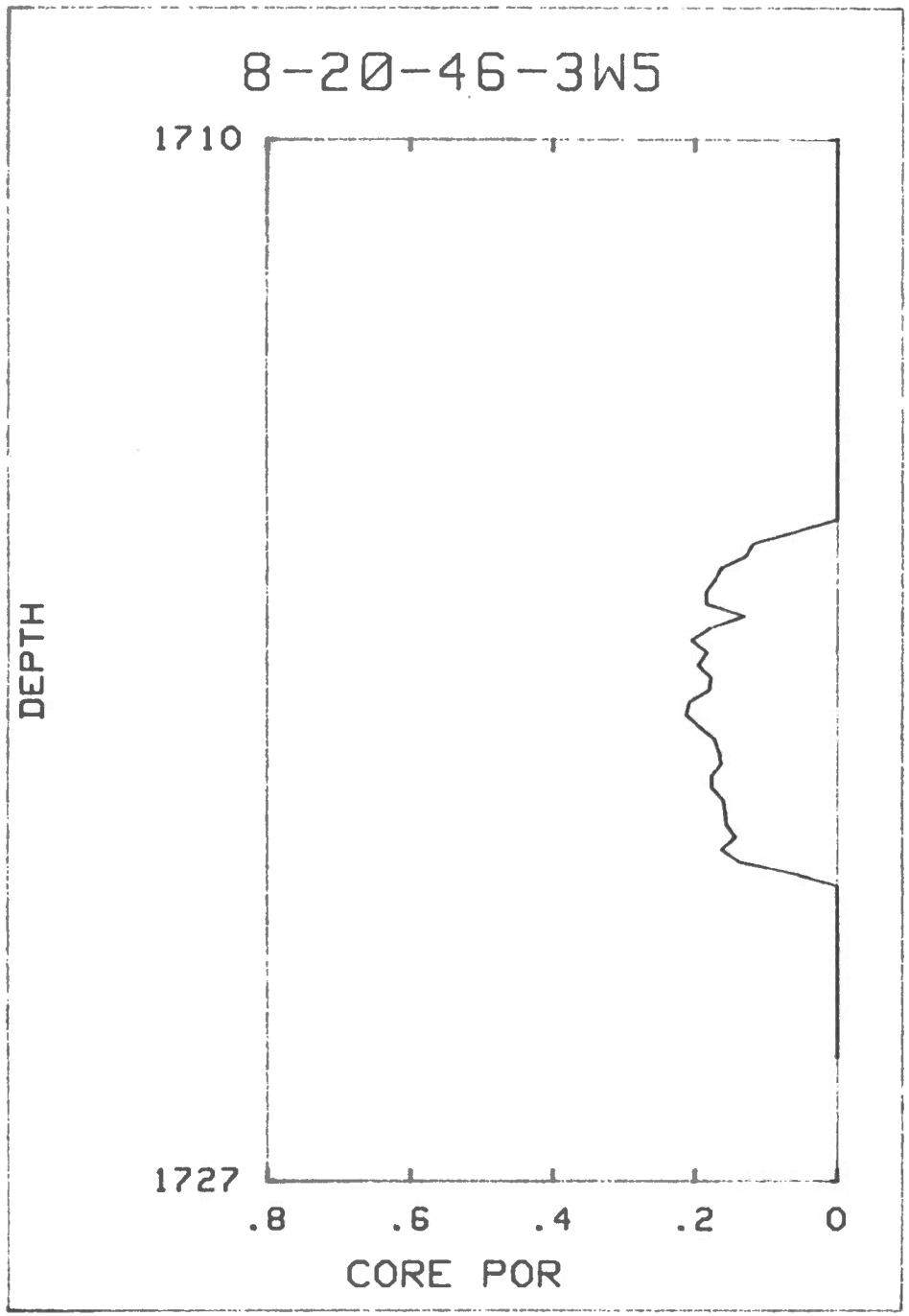



6-20-46-3W5
1718
1735
DEPTH
.8
.6
.4
.2
0
CORE POR

WELL NAME Bumper Crystal (4" diameter; partially slabbed)

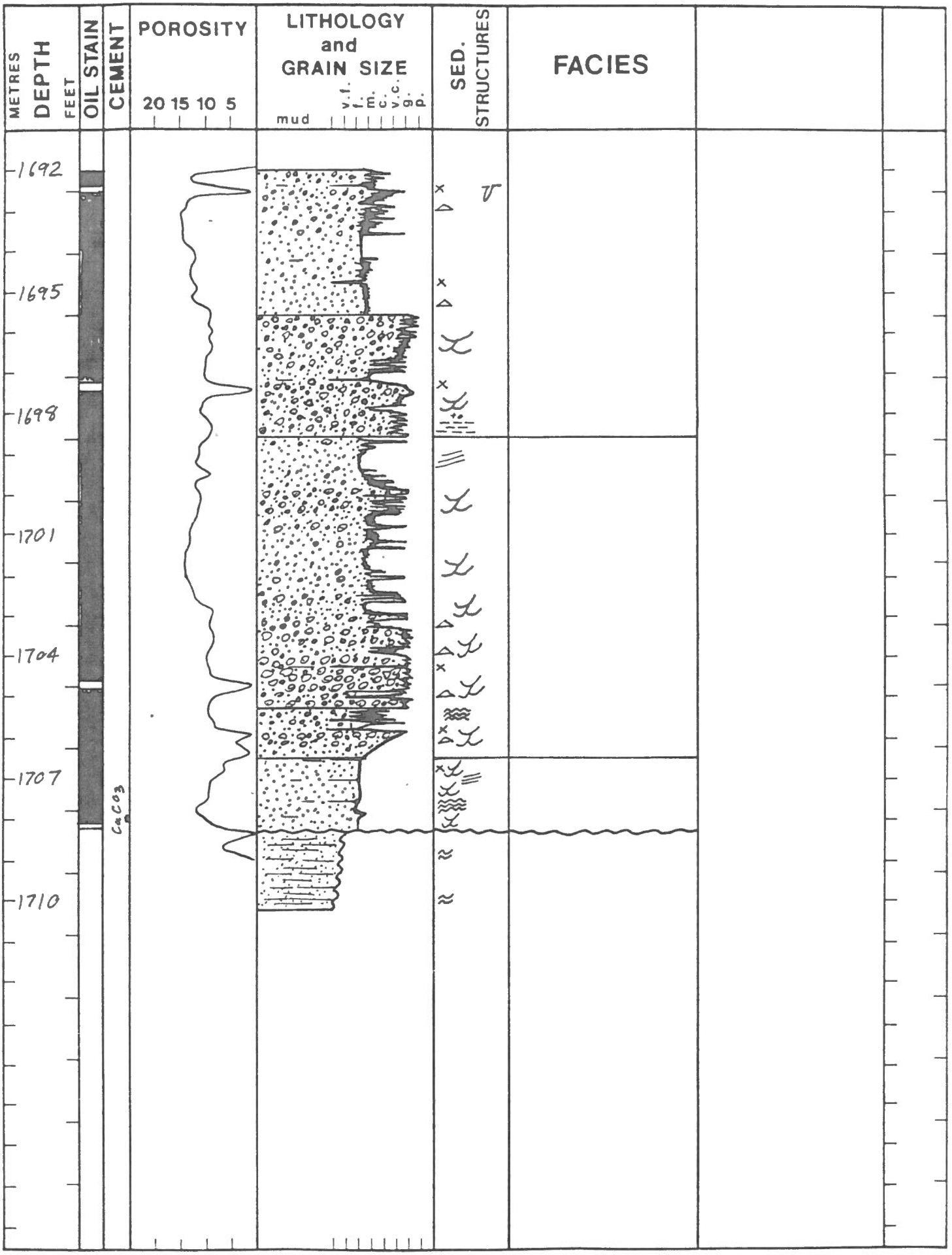
LOCATION 8-20-46-3W5 CORE INTERVAL 1711-1729.5 (Rec 18.5)

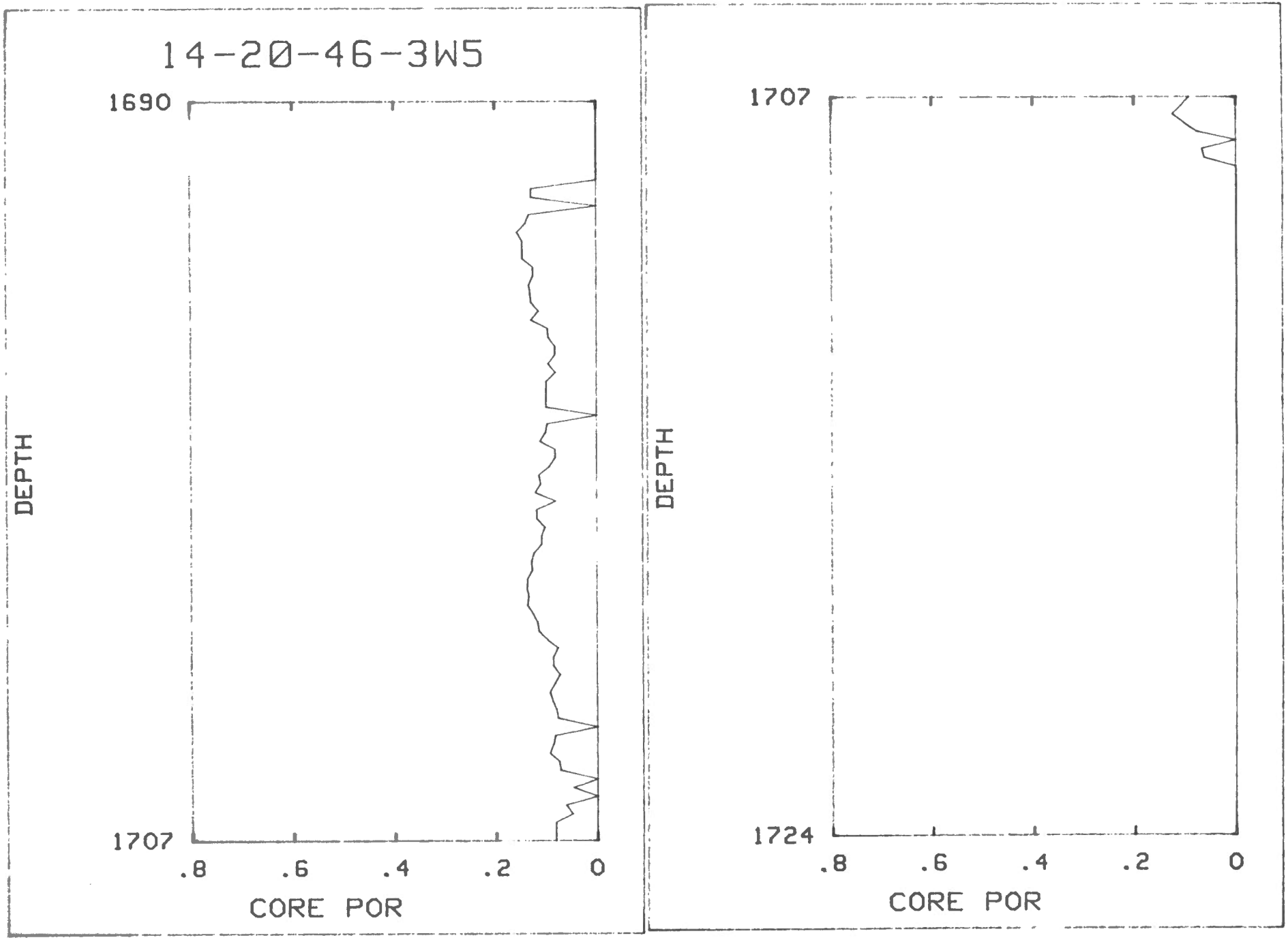



8-20-46-3W5
1710
1727
DEPTH
.8
.6
.4
.2
0
CORE POR

WELL NAME Westcoast et al Crystal (10cm diameter; partially slabbed)

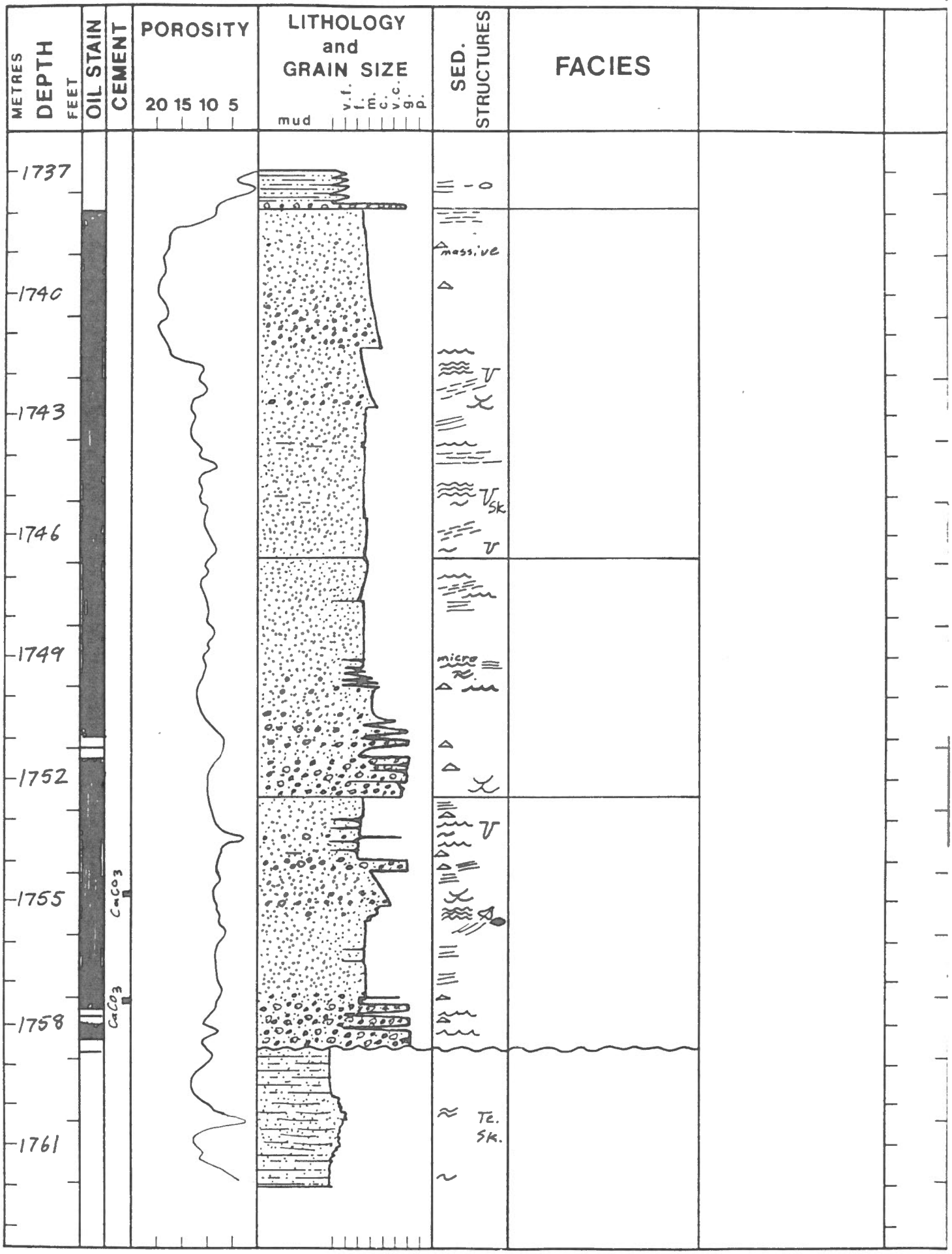
LOCATION 14-20-46-3W5 CORE INTERVAL 1692 - 1710.2 (Rec 17.6)

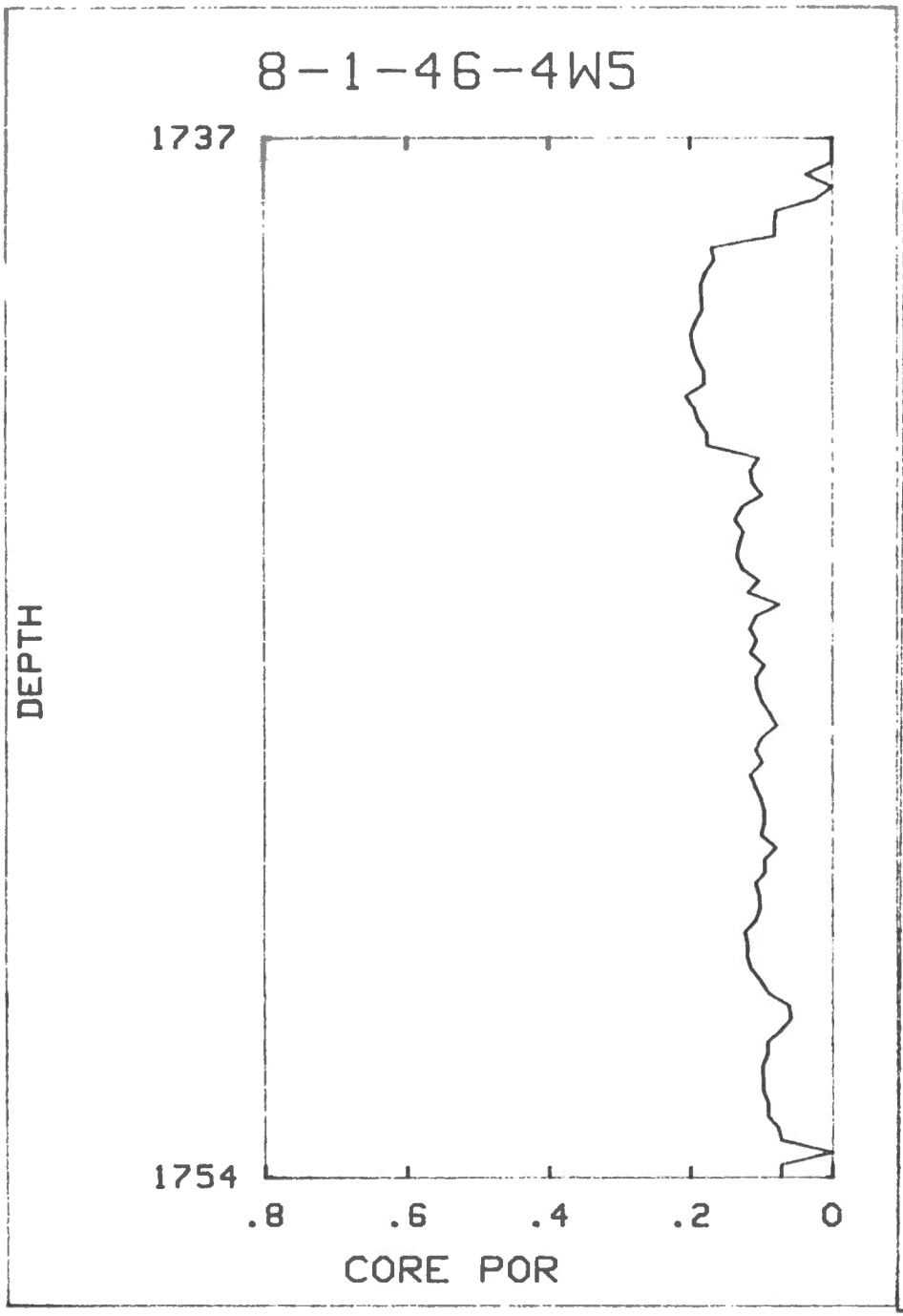


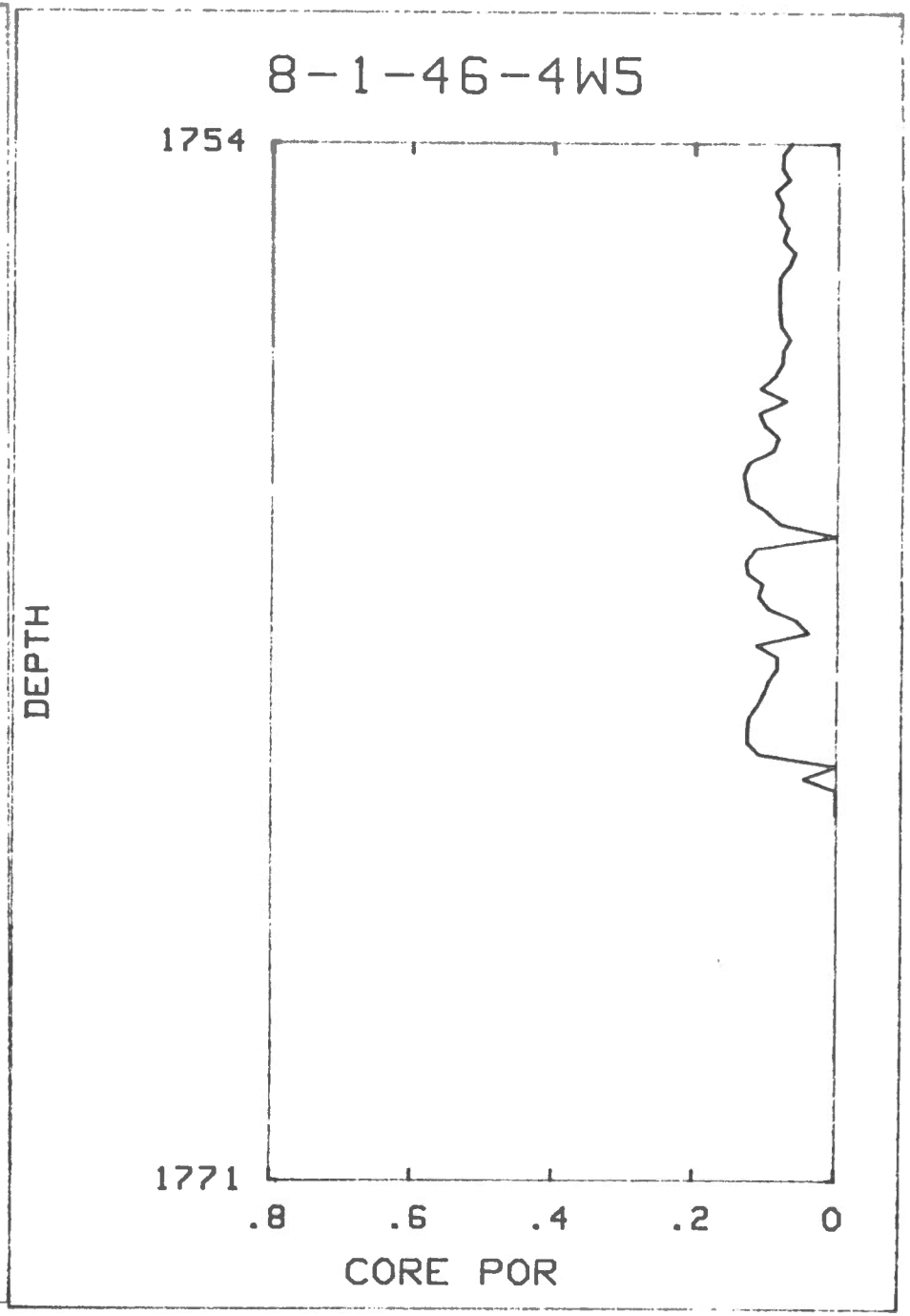

14-20-46-3W5
1690
1707
DEPTH
.8
.6
.4
.2
0
CORE POR
1707
1724
DEPTH
.8
.6
.4
.2
0
CORE POR

WELL NAME ARCTIC PETROCON CRYSTAL (10cm diameter; unslabbed)

LOCATION 8-1-46-4W5 CORE INTERVAL 1737-1755 (Rec 18.2.
1755-1762 (Rec 7.0



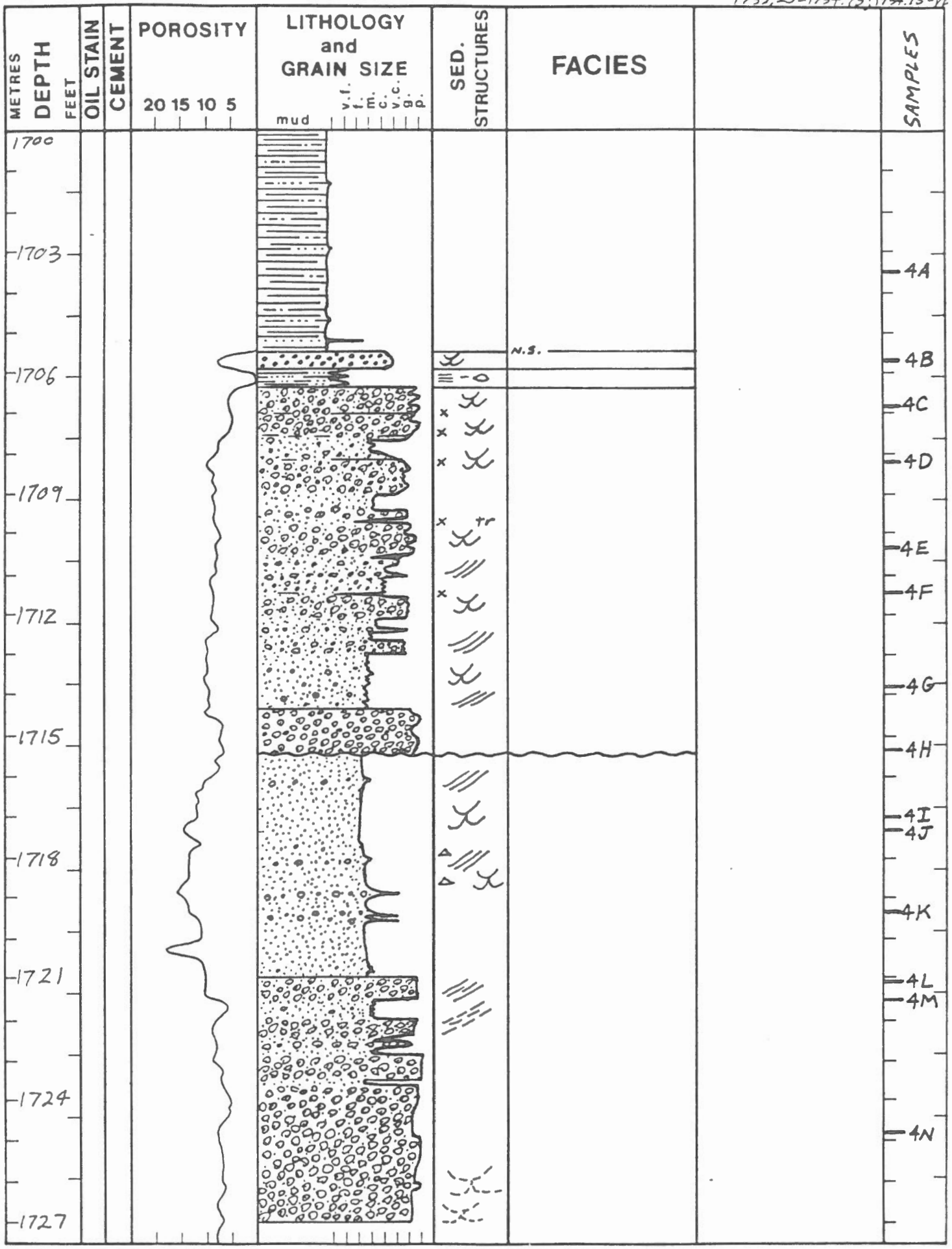

8-1-46-4W5
1737
1754
DEPTH
.8
.6
.4
.2
0
CORE POR


8-1-46-4W5
1754
1771
DEPTH
.8
.6
.4
.2
0
CORE POR

WELL NAME Westcoast et al Crystal (10cm diameter; unslabbed)

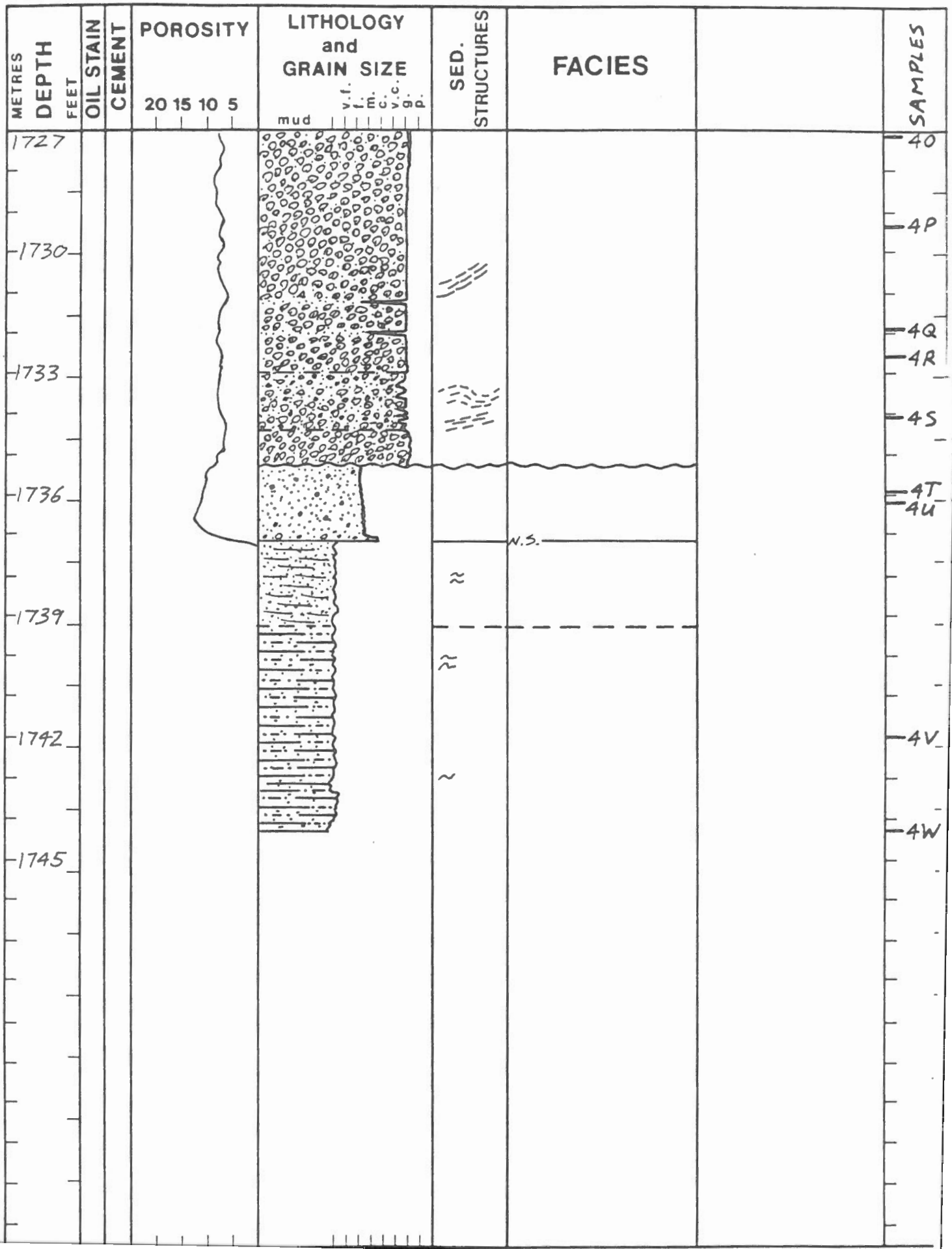
LOCATION 10-1-46-4W5

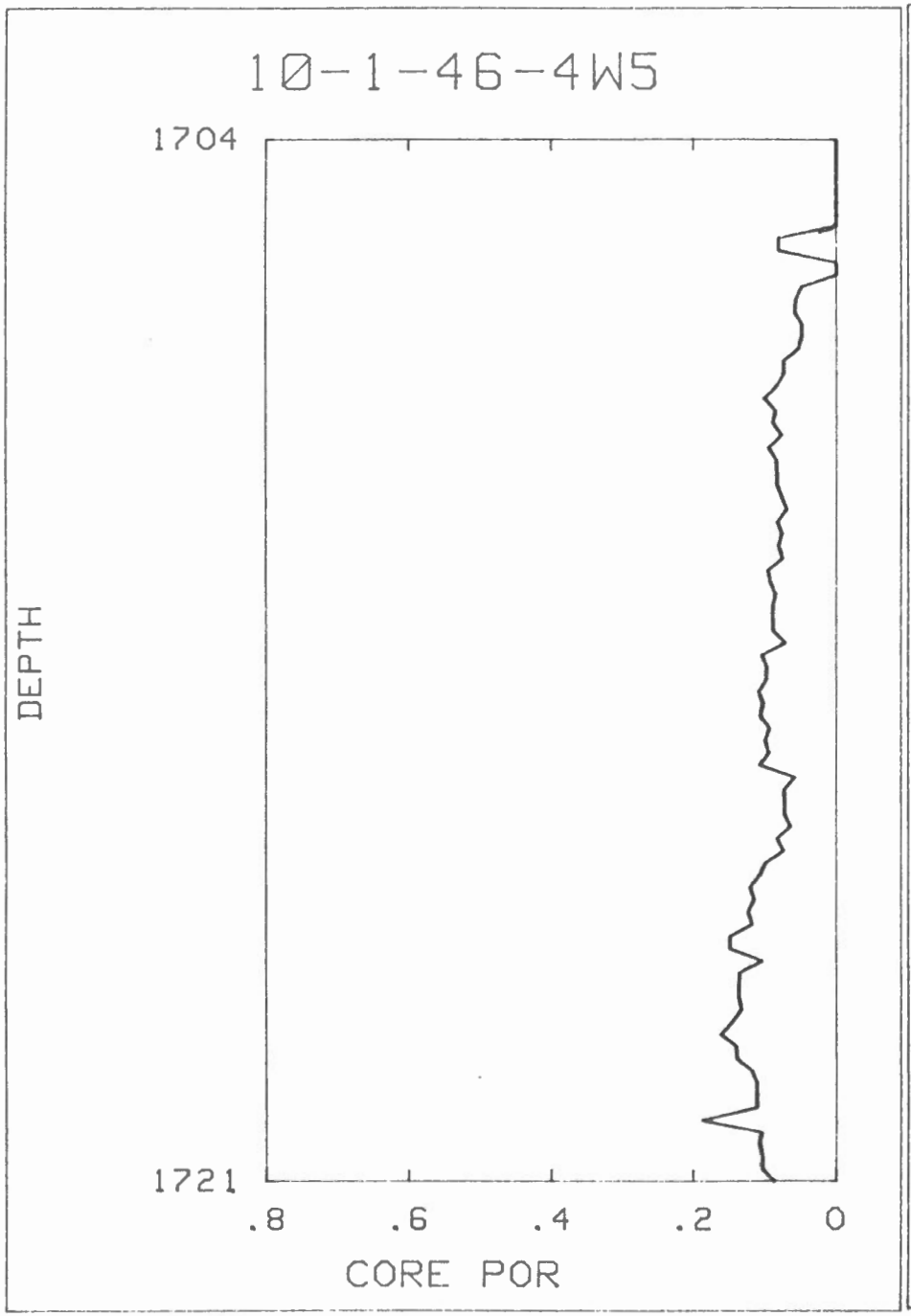
CORE INTERVAL 1700 - 1714.25 (Rec 14.25)
1714.25 - 1732.25 (Rec 18m)
1732.25 - 1734.75; 1734.75 - [illegible]

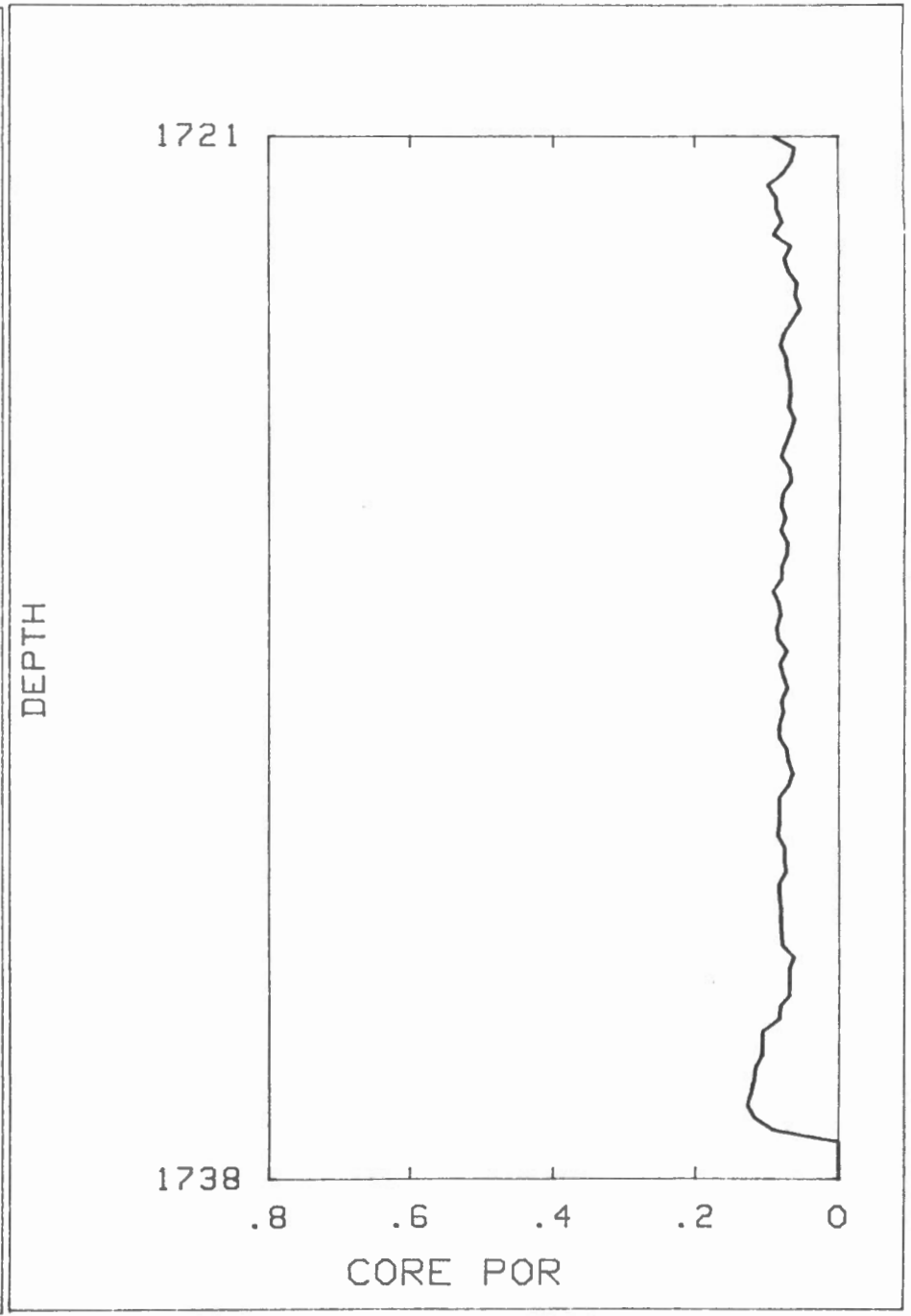


WELL NAME Westcoast et al Crystal (10cm diameter; unslabbed)

LOCATION 10-1-46-4W5 Continued CORE INTERVAL

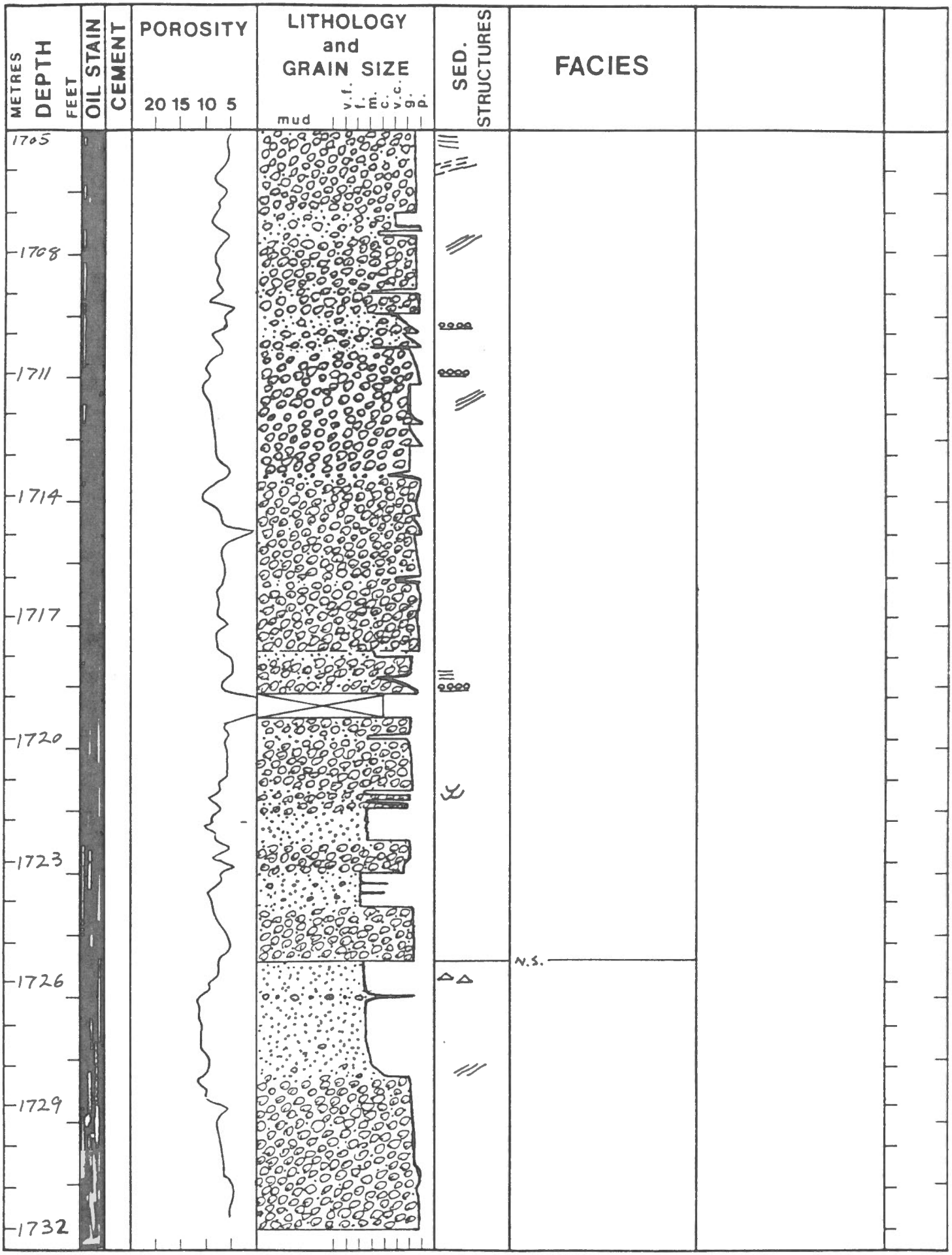



10-1-46-4W5
1704
1721
DEPTH
.8
.6
.4
.2
0
CORE POR


1721
1738
DEPTH
.8
.6
.4
.2
0
CORE POR

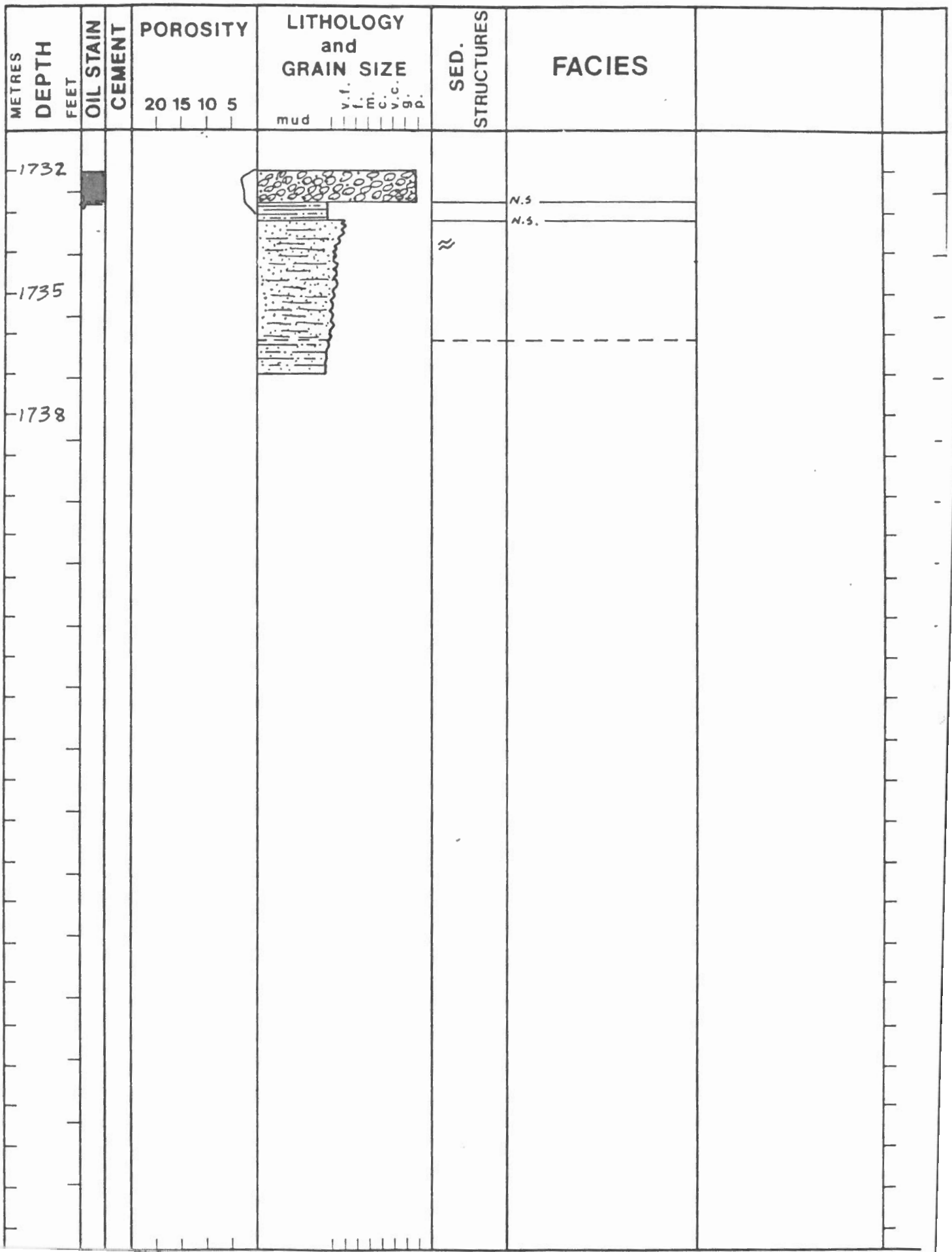
WELL NAME WESTCOAST et al Crystal (10cm diameter, 3160mCm)

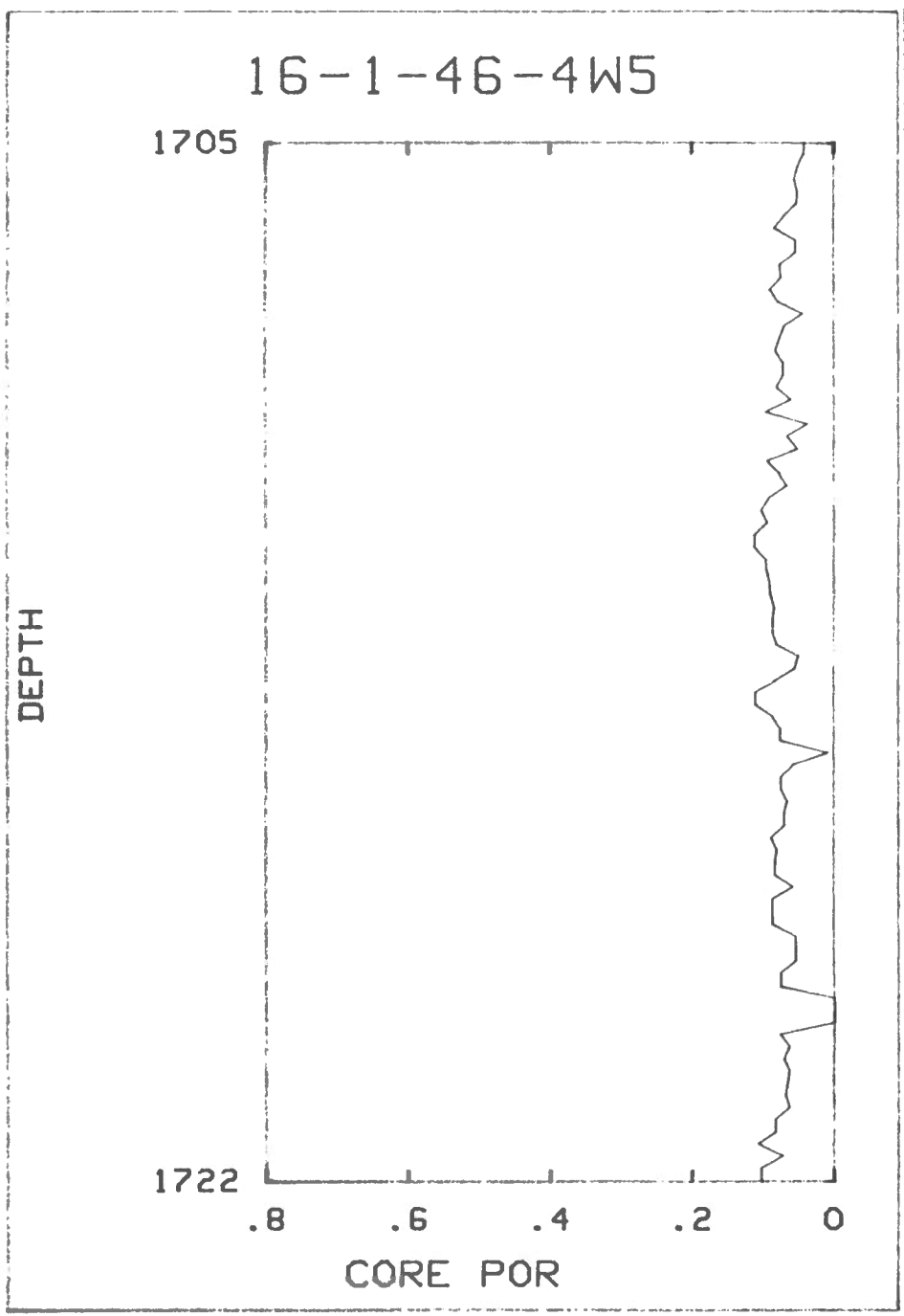
LOCATION 16-1-46-4w5 CORE INTERVAL 1705-1719.5 (Rec 13.
1719.5-1737.75 (Rec 17.6

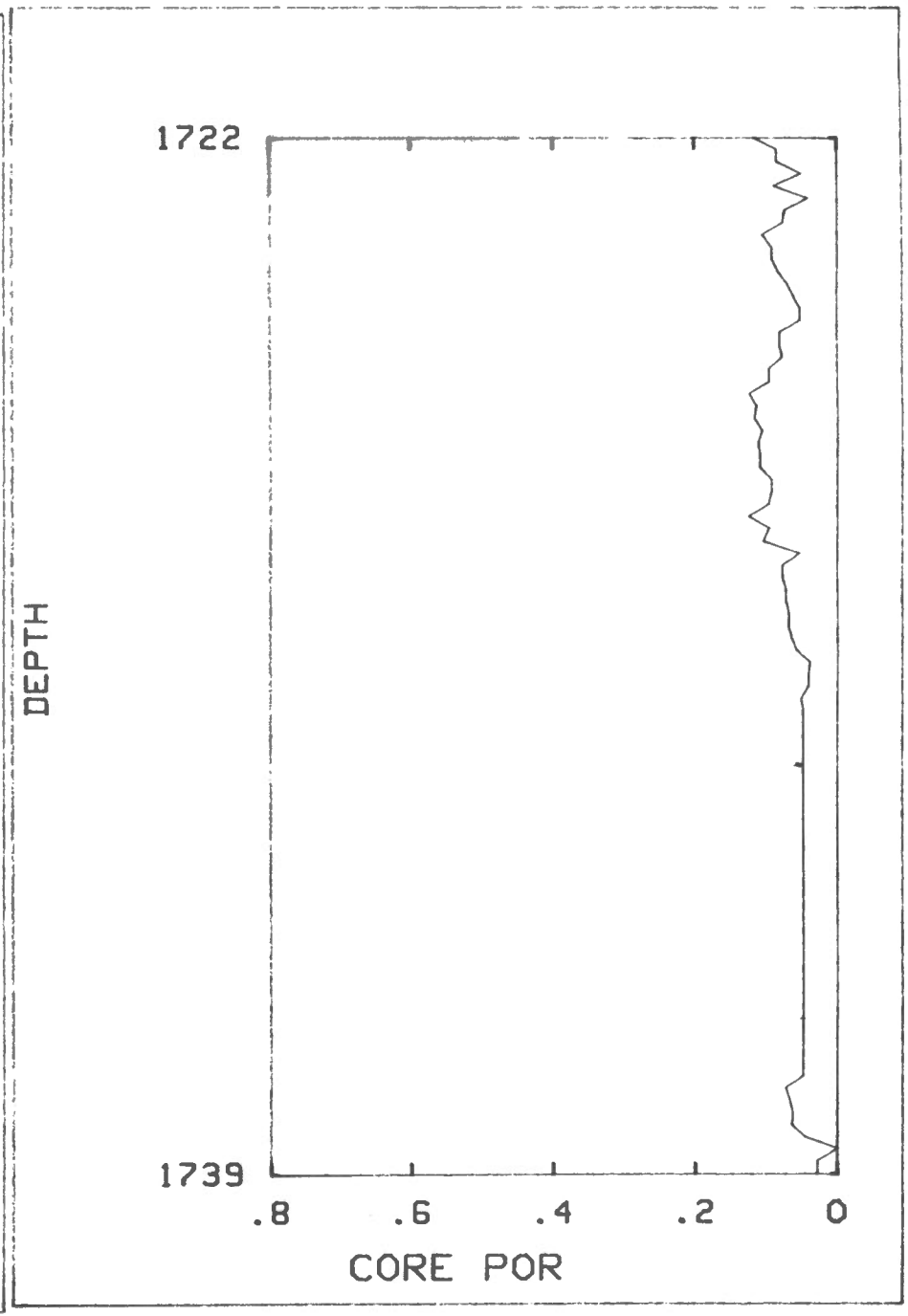


WELL NAME West coast et al Crystal

LOCATION 16-1-46-4 w5 (Continued) CORE INTERVAL 1719.5-1737.75 (Rec 17

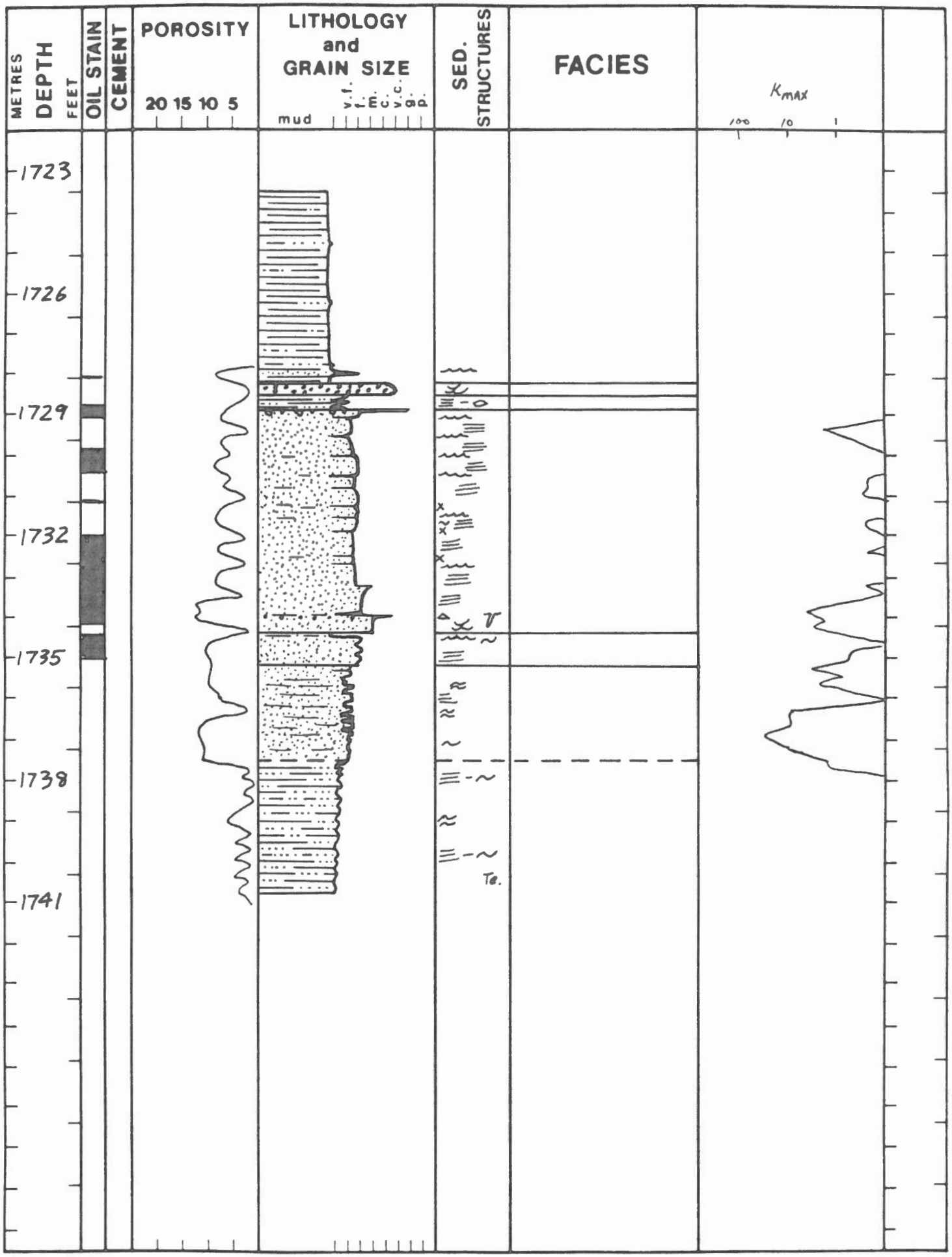


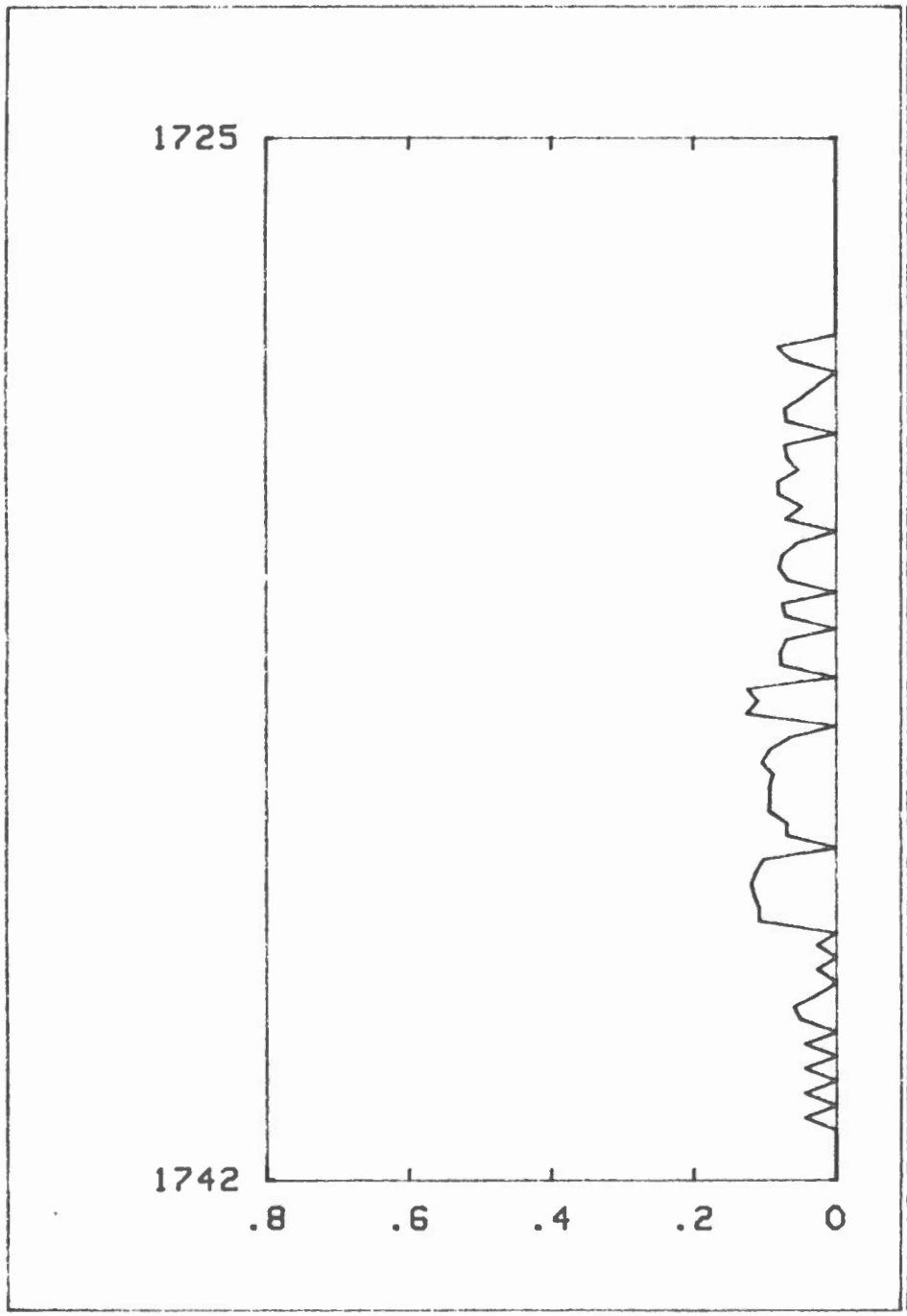

16-1-46-4W5
1705
1722
DEPTH
.8
.6
.4
.2
0
CORE POR

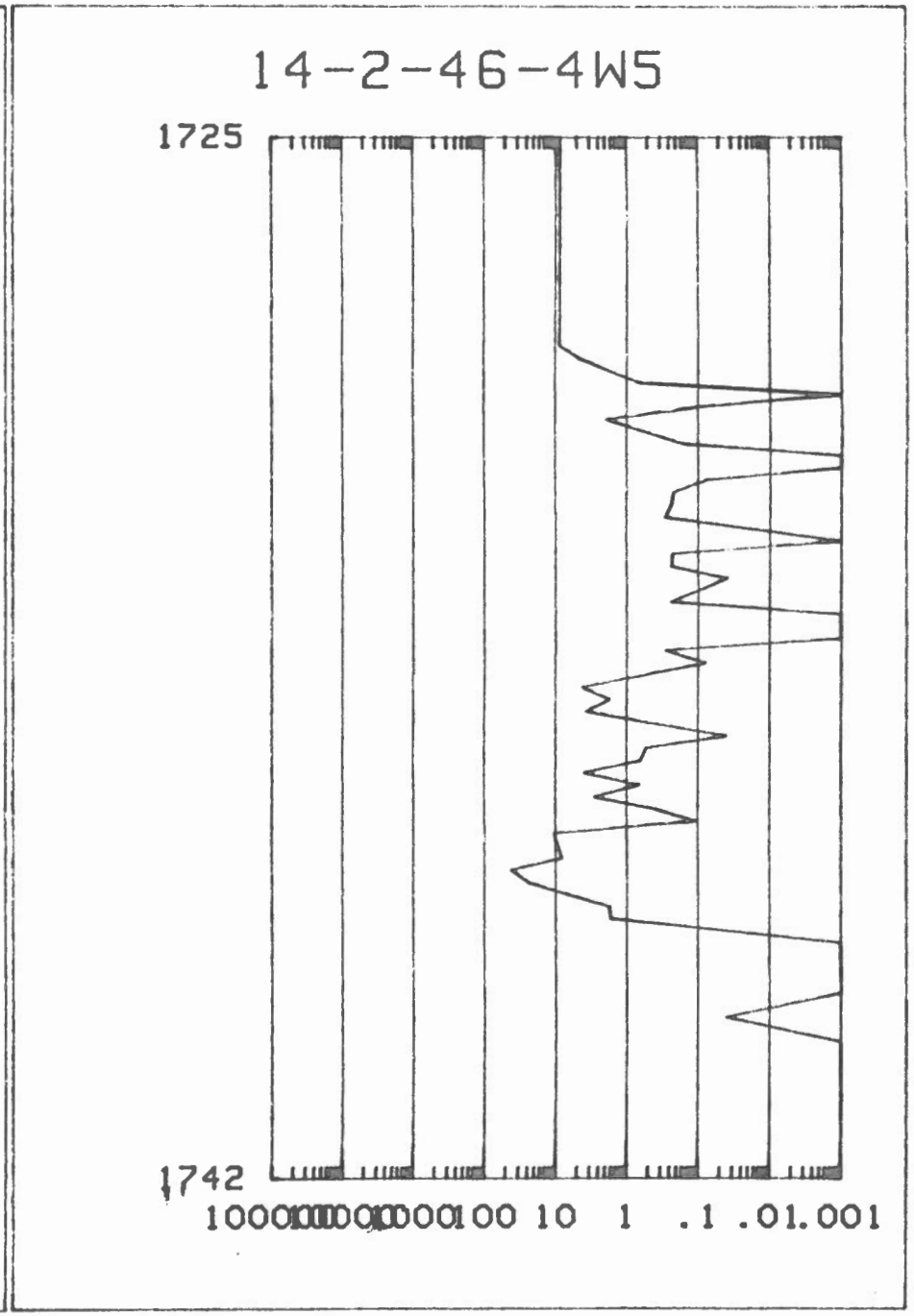

1722
1739
DEPTH
.8
.6
.4
.2
0
CORE POR

WELL NAME [illegible]

LOCATION 14-2-46-4W5 CORE INTERVAL 1723.5-1733.25 (Rec 9.75.)
1733.25-1740.75 (Rec 7.5.)

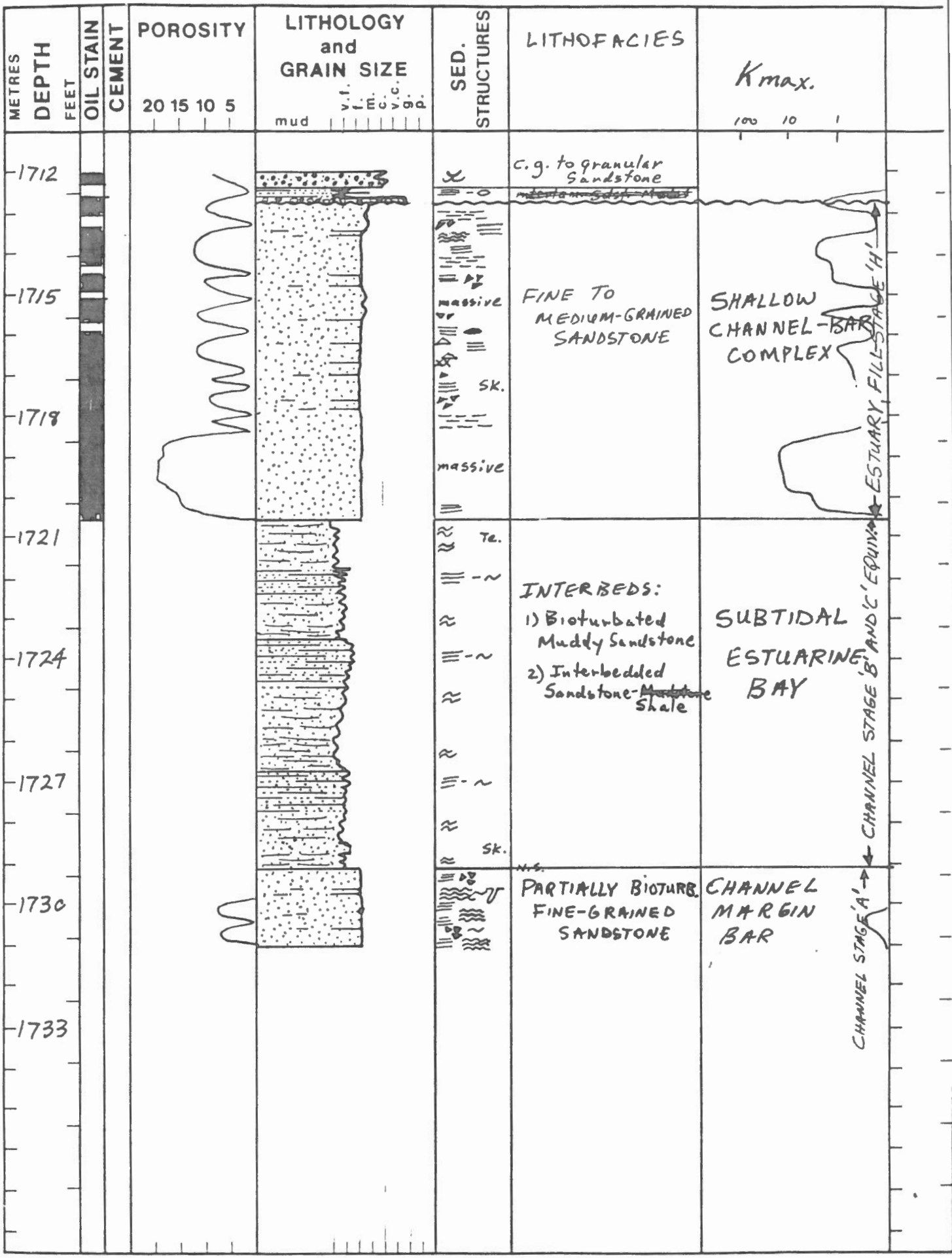


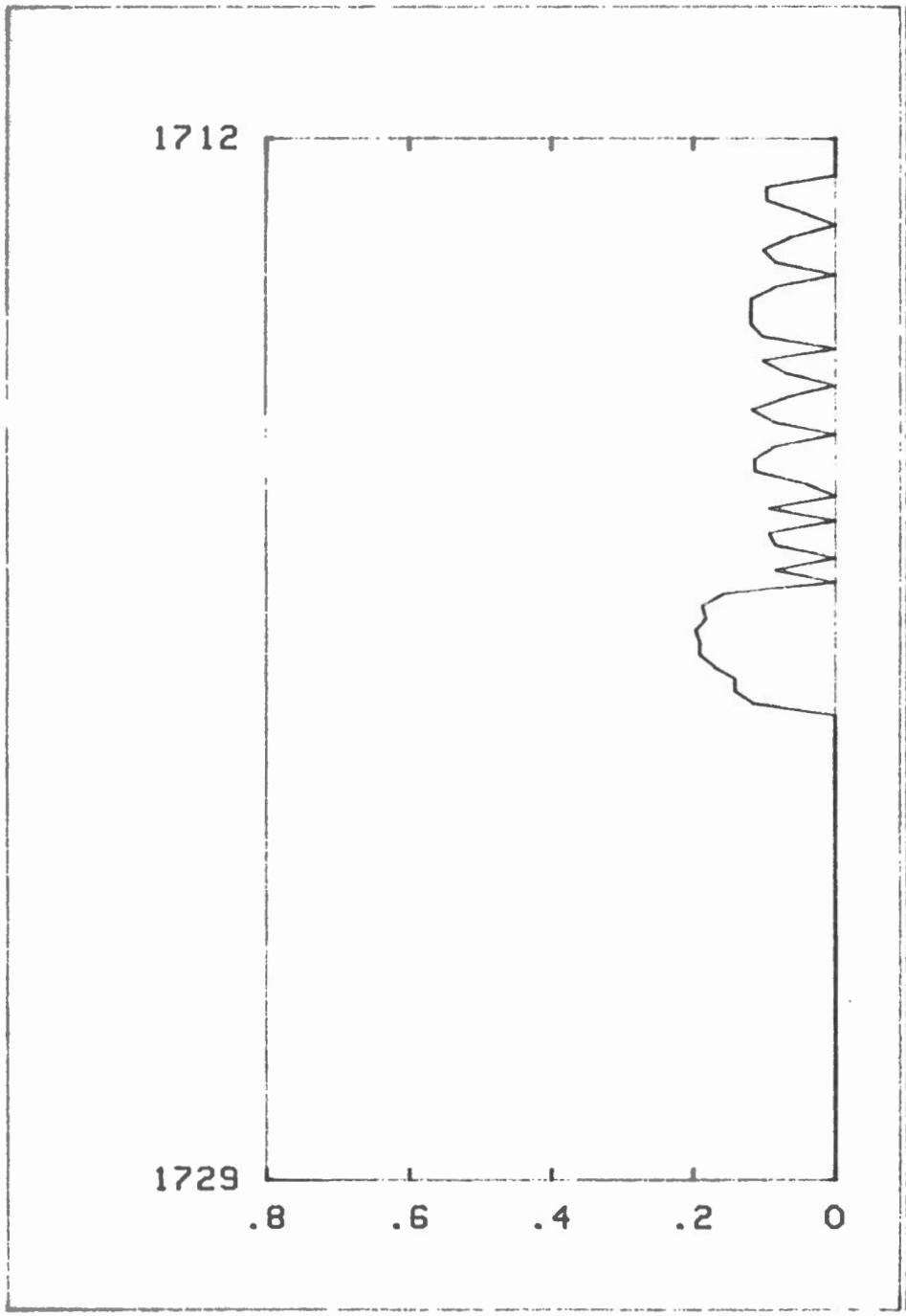

1725
1742
.8
.6
.4
.2
0

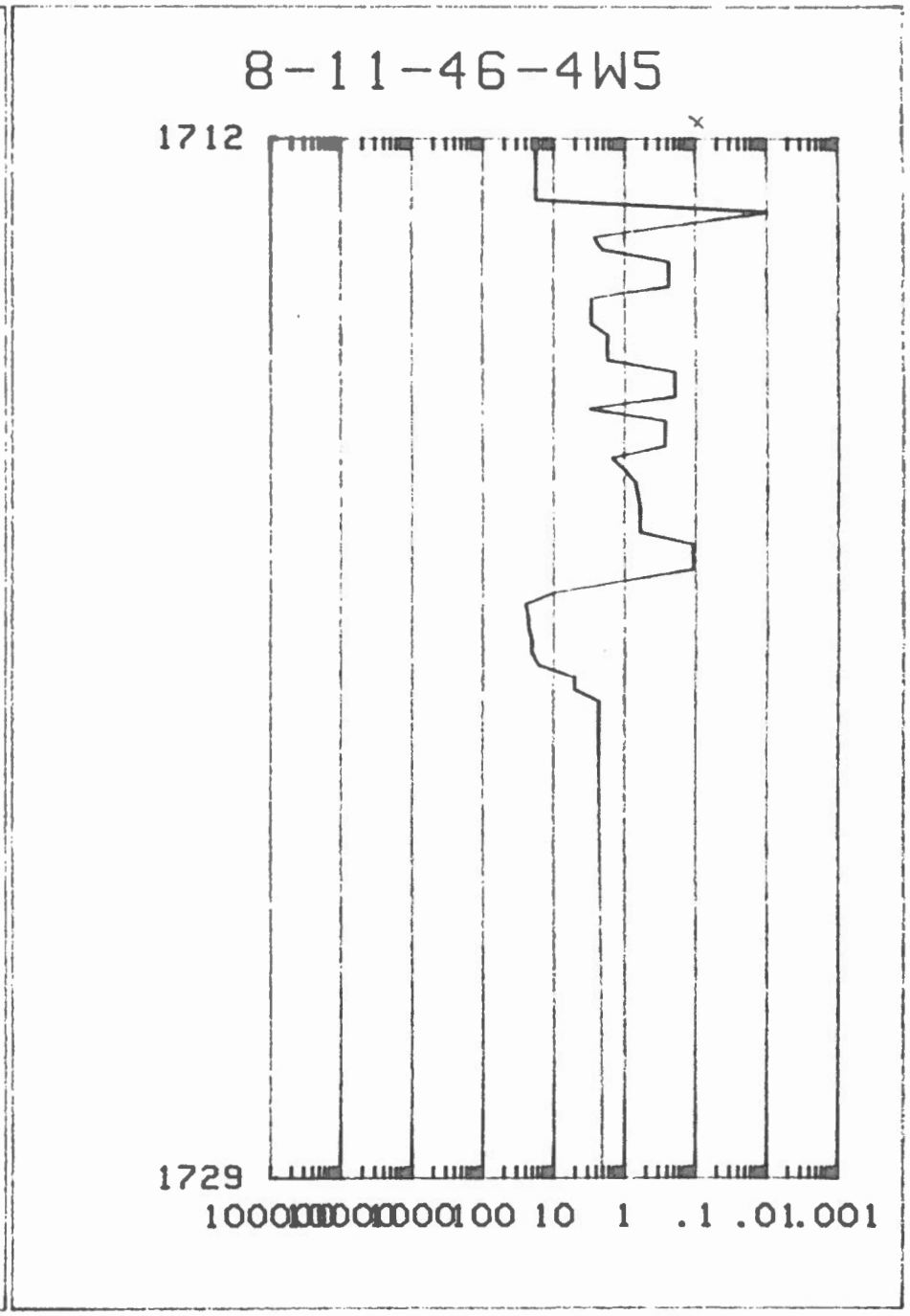

14-2-46-4W5
1725
1742
1000
100
10
1
.1
.01
.001

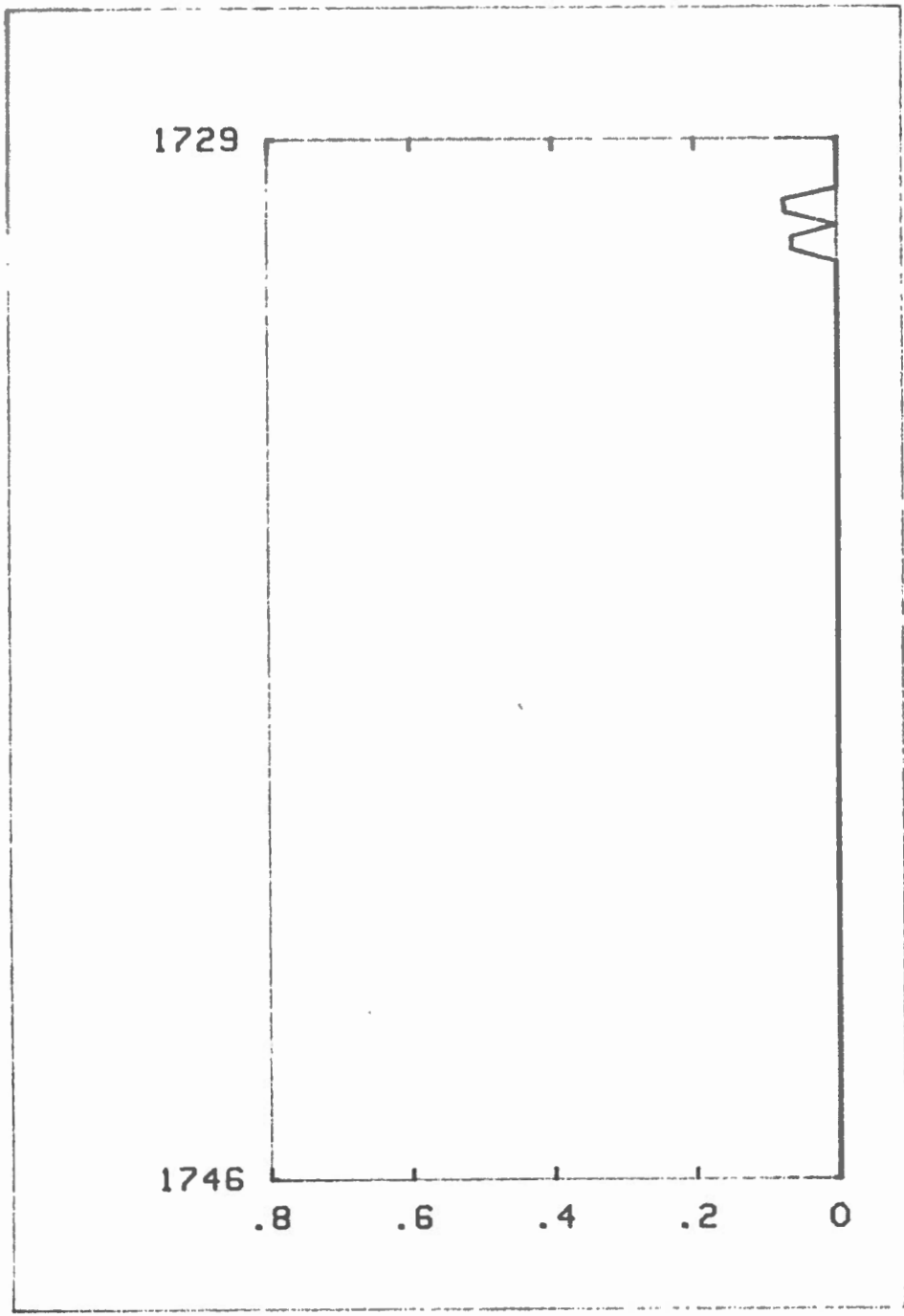
WELL NAME Westcoast Bluesky Crystal

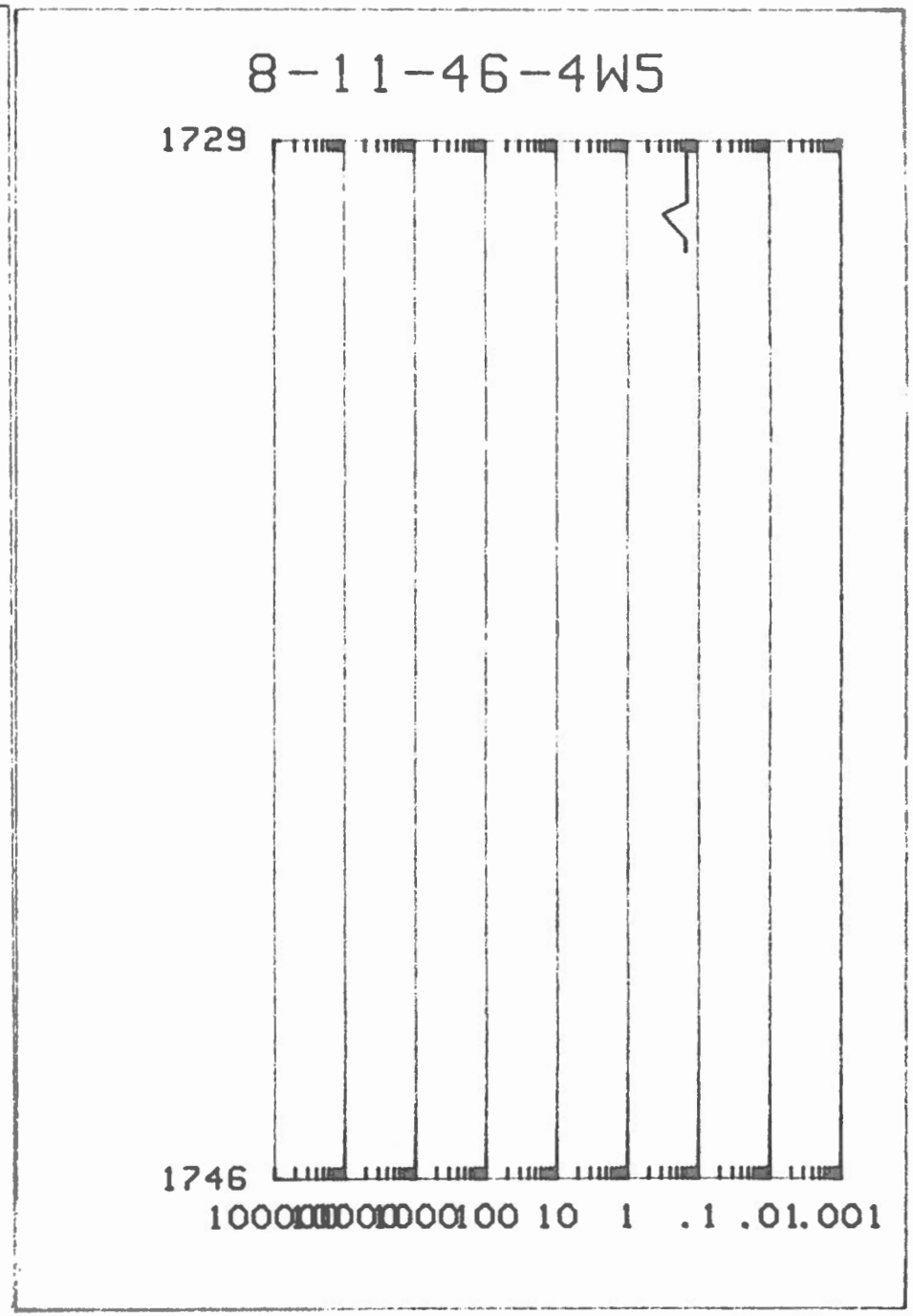
LOCATION 8-11-46-4W5 CORE INTERVAL 1712-1730.2 (Rec 18.2.)
1730.2-1731.05 (Rec 0.9)




1712
1729
.8
.6
.4
.2
0


8-11-46-4W5
1712
1729
1000
100
10
1
.1
.01
.001


1729
1746
.8
.6
.4
.2
0


8-11-46-4W5
1729
1746
1000
100
10
1
.1
.01
.001

APPENDIX III

List of core samples submitted with this report

SAMPLE NO.	WELL	DEPTH	LITHOLOGY
1A	16-30-46-3W5	1675.3	Shale
1B	"	1675.9	Sandstone
1C	"	1676.4	Bioturbated muddy sst
1D	"	1679.8	Interbedded Mdst/sst
1E	"	1681.8	Conglomerate
1F	"	1684.4	Conglomerate
1G	"	1688.9	Interbedded Mdst/sst
1H	"	1689.2	Sandstone
1I	"	1690.5	Conglomerate
1J	"	1693.0	Mudstone
2A	6-20-46-3W5	1723.2	Conglomerate
2B	"	1725.2	Sandstone
2C	"	1725.3	Sandstone
2D	"	1726.9	Conglomerate
2E	"	1728.9	Sandstone
2F	"	1731.9	Sandstone
2G	"	1733.7	Sandstone
2H	"	1734.6	Bioturbated Muddy sst
2I	"	1737.3	Bioturbated Muddy sst
3A	3-18-46-3W5	1685.5	Sandstone
3B	"	1689.0	Sandstone
3C	"	1692.4	Sandstone
3D	"	1693.8	Sandstone
3E	"	1696.6	Sandstone
3F	"	1699.8	Sandstone
3G	"	1701.0	Sandstone
3H	"	1703.2	Mudstone
3I	"	1706.7	Mudstone
4A	10-1-46-4W5	1703.5	Shale
4B	"	1705.7	Sandstone
4C	"	1706.8	Conglomerate
4D	"	1708.2	Conglomerate sst
4E	"	1710.3	Conglomerate
4F	"	1711.4	Conglomeratic sst
4G	"	1713.8	Sandstone
4H	"	1715.3	Conglomerate
4I	"	1717.0	Sandstone
4J	"	1717.3	Sandstone
4K	"	1719.3	Sandstone
4L	"	1721.1	Conglomerate
4M	"	1721.5	Conglomerate
4N	"	1724.8	Conglomerate
4O	"	1727.1	Conglomerate
4P	"	1729.3	Conglomerate
4Q	"	1731.9	Conglomerate
4R	"	1732.7	Conglomerate

SAMPLE NO.	WELL	DEPTH	LITHOLOGY
4S	"	1734.1	Conglomerate
4T	"	1735.9	Sandstone
4U	"	1736.2	Sandstone
4V	"	1742.0	Mudstone
4W	"	1744.3	Mudstone
5A	8-31-45-3W5	1782.0	Shale
5B	"	1784.2	Shale
5C	"	1785.9	Sandstone
5D	"	1788.4	Sandstone
5E	"	1791.5	Sandstone
5F	"	1792.6	Sandstone
5G	"	1796.4	Bioturbated Muddy sst
5H	"	1800.5	Mudstone
5I	"	1802.8	Mudstone
6A	8-26-45-4W5	1813.8	Sandstone
6B	"	1817.0	Sandstone
6C	"	1828.5	Sandstone
6D	"	1831.5	Sandstone
7A	16-24-45-4W5	1785.7	Shale
7B	"	1787.9	Sandstone
7C	"	1790.25	Sandstone
7D	"	1792.7	Sandstone
7E	"	1796.51	Sandstone
7F	"	1800.9	Sandstone
7G	"	1805.4	Sandstone
7H	"	1807.9	Sandstone
7I	"	1809.5	Mudstone