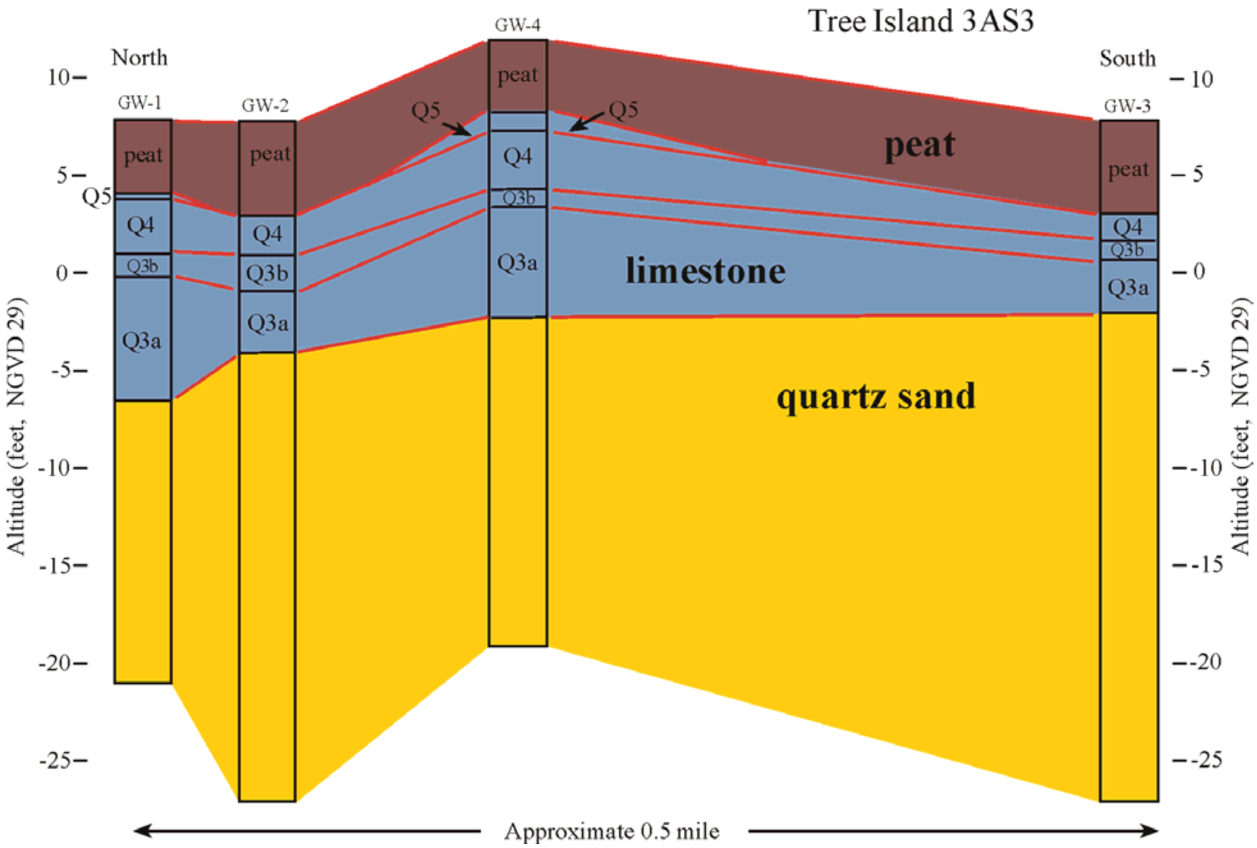
HYDROSTRATIGRAPHY OF TREE ISLAND CORES FROM WATER CONSERVATION AREA 3



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HYDROSTRATIGRAPHY OF TREE ISLAND CORES FROM WATER CONSERVATION AREA 3

ABSTRACT

Cores and borehole-geophysical logs collected on and around two tree islands in Water Conservation Area 3 have been examined to develop a stratigraphic framework for these ecosystems. Especially important is the potential for the exchange of ground water and surface water within these features. The hydrostratigraphic results from this study document the lithologic nature of the foundation of the tree islands, the distribution of porous intervals, the potential for paleotopographic influence on their formation, and the importance of low-permeability, subaerial-exposure horizons on the vertical exchange of ground water and surface water.

Results from this hydrostratigraphic study indicate that subtle differences occur in lithofacies and topography between the on-island and off-island subsurface geologic records. Specifics are described herein. Firstly, at both tree-island sites, the top of the limestone bedrock is slightly elevated beneath the head of the tree islands relative to the off-island core sites and the tail of the tree islands, which suggests that bedrock "highs" acted as "seeds" for the development of the tree islands of this study and possibly many others. Secondly, examination of the recovered core and the caliper logs tentatively suggest that the elevated limestone beneath the tree islands may have a preferentially more porous framework relative to limestone beneath the adjacent areas, possibly providing a ground-water-to-surface-water connection that sustains the tree island system. Finally, because the elevation of the top of the limestone bedrock at the head of Tree Island 3AS3 is slightly higher than the surrounding upper surface of the peat, and because the wetland peats have a lower hydraulic conductivity than the limestone bedrock (Miami Limestone and Fort Thompson Formation), it is possible that there is a head difference between surface water of the wetlands and the ground water in underlying limestone bedrock.

INTRODUCTION

Cores from eight test coreholes from two tree islands in Water Conservation Area 3 (WCA-3) were described and spatially correlated based on lithology, subaerial-related discontinuity horizons, and gamma-ray wireline logs. Four of the cores and geophysical logs were from Tree Island 3AS3, and four of the cores and geophysical logs were collected from Tree Island 3BS1 (Figure 1). The purpose of this hydrostratigraphic study was to characterize the shallow subsurface geology and provide stratigraphic correlation in order to: (1) identify key zones of porosity that may provide linkage between ground-water and surface-water systems which help to sustain the tree island habitats; and (2) identify any anomalous geologic features that may have contributed to the initial formation and continued sustainability of the tree-island systems.

SUBSURFACE LITHOLOGY

Lithologic units in the eight cores were determined based on vertical changes in sediment type and fossil content, and the nature of the contacts between the adjacent lithologies. The presence of features related to subaerial exposure of the carbonates was often used to delineate the rock-unit boundaries (Q-units) or to infer the presence of the upper bounding surface of a subaerial discontinuity not recovered as core. The "Q" terminology ("Q" represents Quaternary) is used for these rock units. This terminology is modified from Perkins (1977), who first recognized that the Miami Limestone and Fort Thompson Formation of South Florida are comprised of five unconformity-bound, time-stratigraphic marine units. These units were informally termed, from oldest to youngest, Q1 through Q5 ("Q" represents Quaternary) and a Pleistocene age is assigned to the Q-units (Perkins, 1977). Quartz sands were encountered in the lower portions of Tree Island 3AS3 and have been assigned to the Pliocene Pinecrest Member of the Tamiami Formation. Thin sections were used to confirm the core-based lithologic classification and to confirm the nature of the pore types.

Methods

The carbonate classification of Dunham (1962) and Lucia (1995) are used to describe primarily carbonate rocks. The Dunham and Lucia classifications have been modified to incorporate noncarbonate grain types (see modified Dunham classification in appendix II). Grain-size diameters were estimated using a grain-size comparator placed directly on top of the thin section. The percentage of each size range was determined by the comparator in each of the four quadrants and was generally estimated to the closest 5%. Sphericity and roundness were described using photo-comparators developed by Powers (1953) and included in the AAPG (American Association of Petroleum Geologists) Sample Examination Manual (Swanson, 1981). Also, sorting for specific particle grain sizes was described using photo comparators in the AAPG Sample Examination Manual (Swanson, 1981) for specific particle grain sizes. Porosity pore types were classified using the scheme of Lucia (1995). All thin sections were examined with a light microscope using cross-polarized light and transmitted light with uncrossed polarizers. This combination is especially effective for evaluating porosity in blue-dye impregnated sections, sections with microporosity, and sections containing quartz sand. All thin sections were wiped with a light immersion oil to enhance their optical properties. Descriptions of the thin sections and representative photomicrographs are contained in Appendix I. Depths are reported relative to the NGVD 1929 sea-level datum.

Terminology Conventions

Calcrete (caliche) - Surficial material such as sand or gravel or cobbles cemented by calcium carbonate, usually resulting (in part) from subaerial exposure. Also characterized by laminated crusts, soil breccias, root molds, and microstalactitic texture.

Microspar - Used (in this report) to describe any fine-grained calcite crystal. Includes calcite spar greater than the 15-µm limit defined by Folk (1965). Thin-section quality limited many attempts to characterize the exact size of the fine-grained spar cement or matrix.

Mold - A pore formed by selective removal (dissolution) of calcium carbonate particles. Also used (in this report) to include removal particles composed of other mineralogies, such as, phosphate grains.

Peloid - A grain formed of cryptocrystalline carbonate, which ranges in size from silt to gravel, although most are in the fine to coarse sand range.

Spar - A calcite that is sufficiently coarse in crystal size to appear relatively transparent in thin section and each crystal can be identified in polarized light. Calcite crystal morphologies are often described as blocky, bladed, and fibrous and replace large skeletal fragments and infill molds.

Soil Breccia - Usually an intraclast floatstone formed from brecciation of subaerial exposed limestone at major discontinuity horizons.

Vug – An opening in rock matrix that is large enough to be seen with the unaided eye. Vugs are usually equant in dimensions; however, the modifier "elongate" is used where the length to width ratio is greater than 3 to 1.

Description of Tree Island 3AS3 Cores

Four cores were continuously drilled from four test corehole sites on and around Tree Island 3AS3 (Figure 1) by the South Florida Water Management District. Results of the core analyses are summarized in Technical Publication WS-4 (Bevier and Krupa, 2001). Cores 3AS3-GW1 and 3AS3-GW2 were collected off the northwest and northeast edges of the tree island, respectively. Cores 3AS3-GW3 and 3AS3-GW4 were collected on the southern and northern ends of the tree island, respectively. Test corehole information is summarized in Table 1; core descriptions and graphic summaries are presented in Appendix II; and core photographs are shown in Appendix III.

Core 3AS3-GW1 (off island to northwest)

Test corehole 3AS3-GW1 penetrated 4.0 ft of peat and organic sediment, 10.5 ft of limestone, and 13.5 ft of mainly quartz sand admixed with some carbonate sediment. Within the carbonate sediment, four distinct lithologic units were identified. From top to bottom, the units are: (1) a peloidal packstone unit containing encrusting bryozoan fragments; (2) a subaerial discontinuity horizon overlying a lime wackestone unit that shows evidence of root penetration; (3) a lime wackestone-packstone unit with intervals of bedded carbonate sand, and probably capped by a subaerial discontinuity; and (4) an oyster and gastropod floatstone unit containing a lime packstone matrix.

Core 3AS3-GW2 (off island to northeast)

Test corehole 3AS3-GW2 penetrated 5.0 ft of peat and organic sediment, 6.0 ft of limestone, and 23.0 ft of predominantly quartz sand admixed with some carbonate sediment. This lowermost quart sand may be equivalent to the lower part of the Fort Thompson Formation or the uppermost Pinecrest sand member of the Tamiami Formation. Three lithologic units were identified in the carbonate section. From top to bottom, the units are: (1) a subaerial discontinuity horizon overlying an intraclast floatstone (soil breccia); (2) a lime packstone-grainstone unit composed mainly of skeletal sands with a basal unit that is a laminated calcrete; and (3) an intraclast floatstone with matrix of quartz sand and lime mud with oyster fragments, likely part of a soil breccia.

Core 3AS3-GW3 (on island south end)

Test corehole 3AS3-GW3 penetrated 5.0 ft of peat and organic sediment, 4.6 ft of limestone, and 24.4 ft of predominantly quartz sand admixed with some carbonate sediment. Within the carbonate section, three distinct lithologic units were identified. From top to bottom, the units are: (1) a lime wackestone-mudstone unit with calcrete, root structures and oxidation staining—the effects of subaerial exposure processes; (2) a thin interval of lime packstone-grainstone composed of skeletal sands; and (3) an intraclast floatstone with laminated calcrete in a matrix of mixed lime mud and quartz sand, likely a soil breccia associated with subaerial exposure.

Core 3AS3-GW4 (on island north end)

Test corehole 3AS3-GW4 penetrated 3.5 ft of peat and organic sediment, 8.8 ft of limestone, and 17.7 ft of predominantly quartz sand admixed with some carbonate sediment. Four lithologic units were identified in the carbonate section. From top to bottom, the units are: (1) a calcrete-capped peloidal sand unit containing bivalves and encrusting bryozoan fragments; (2) a laminated calcrete-capped lime mudstone-wackestone unit with root structures and blackened intraclasts that are likely the result of subaerial exposure; (3) a relatively thin lime packstone-grainstone unit composed of skeletal sand with a minor amount of lime mud (micrite); and (4) an oyster and intraclast floatstone with a lime packstone-wackestone matrix.

Description of Tree Island 3BS1 Cores

Cores from four test coreholes were collected on and around Tree Island 3BS1 (Figure 1) by the South Florida Water Management District and summarized in Technical Publication WS-4 (Bevier and Krupa, 2001). Cores 3BS1-GW1 and 3BS1-GW2 were collected off the northwest and northeast edges of the tree island, respectively. Cores 3BS1-GW3 and 3BS1-GW4 were collected on the southern and northern ends of the tree island, respectively. Test corehole information is summarized in Table 1, core descriptions and graphic summaries are presented in Appendix II, and core photographs are shown in Appendix III.

Core 3BS1-GW1 (off island to northwest)

Test corehole 3BS1-GW1 penetrated 5.0 ft of peat-organic sediment and 28.5 ft of limestone. Five distinct lithologic units were identified in the carbonate section. From top to bottom, the units are: (1) a peloidal and skeletal lime grainstone-packstone with encrusting bryozoan fragments; (2) a lime wackestone containing and capped by laminated calcretes, and containing soil breccias and root structures associated with subaerial exposure; (3) mixed intervals of lime wackestone and packstone with marine skeletal sands; (4) a lime wackestone-packstone unit containing intervals of gastropod (*Planorbella* sp.) related to freshwater limestone; and (5) a lime packstone and bivalve floatstone unit with marine skeletal sands.

Core 3BS1-GW2 (off island to northeast)

Test corehole 3BS1-GW2 penetrated 5.5 ft of peat and organic sediment and 23.5 ft of limestone. In the carbonate section, five distinct lithologic units were identified. From top to bottom, the units are: (1) a peloidal packstone-grainstone unit with bryozoan fragments; (2) a calcrete-capped marine lime wackestone-packstone interval containing several calcrete horizons and other subaerial exposure features, such as roots structures and blackened intraclasts; (3) an interval of lime wackestone-mudstone containing marine sands with intraclast floatstone and calcrete at the top and bottom; (4) a lime wackestone-packstone unit containing intervals of bedded marine limestone and possible freshwater limestone; and (5) lime packstone-wackestone of homogeneous, marine skeletal sands.

Core 3BS1-GW3 (on island south end)

Test corehole 3BS1-GW3 penetrated 5.5 ft of peat and organic sediment and 23.0 ft of limestone. Five distinct lithologic units were identified in the carbonate section. From top to bottom, the units are: (1) a peloidal and skeletal packstone-grainstone including bryozoan fragments; (2) a laminated calcrete-capped wackestone-packstone unit containing a soil breccia, laminated calcrete and root structures related to subaerial exposure; (3) a lime packstone-wackestone with intervals of intraclast floatstone capped by a calcrete-intraclast discontinuity; (4) intervals of wackestone-packstone with bedded marine skeletal sands overlying gastropod-rich units of probable freshwater origin; and (5) a homogeneous lime packstone with skeletal marine sands and minor lime mud.

Core 3BS1-GW4 (on island north end)

Test corehole 3BS1-GW4 penetrated 8.5 ft of peat and organic sediment and 26.5 ft of limestone. In the carbonate section, five distinct lithologic units were identified. From top to bottom, the units are: (1) a peloidal packstone-grainstone; (2) a laminated calcrete-capped marine lime packstone with intraclast floatstone (soil breccia) related to subaerial exposure; (3) an interval of mixed lime wackestone-packstone capped by a laminated calcrete and containing possible soil breccia related to subaerial exposure of a marine limestone; (4) intervals of wackestone-packstone with bedded marine skeletal sands overlying gastropod-rich units of freshwater wackestone; and (5) a homogeneous lime packstone of skeletal marine sand and lime mud.

STRATIGRAPHIC CORRELATION

Methods

The “Q”-unit stratigraphic nomenclature previously described is based on the recognition of five regional Pleistocene age depositional sequences usually bounded by subaerial exposure discontinuities (Perkins, 1977). The present study utilizes this stratigraphic scheme but subdivides unit Q3 into units Q3a and Q3b based on more recent regional lithostratigraphic examination in and around the study area (Cunningham, 2002). The relatively thin limestone section and the higher bedrock elevation (Table 1) at Tree Island 3AS3 makes assignment of the Q-unit designations slightly more difficult relative to the thicker section at the eastern Tree Island 3BS1 site (Figure 1).

Stratigraphy of Tree Island 3AS3 Cores

Examination of the limestone section in cores from Tree Island 3AS3 shows four Q units (Figure 2). Cores 3AS3-GW1 (off island) and 3AS3-GW4 (on island) were the only two cores that recovered the Q5 lithofacies. In these two cores, unit Q5 is relatively thin (~1-2 ft) compared to a thicker section at the more eastern Tree Island 3BS1 site (Figure 3). Units Q4 (lime wackestone with subaerial exposure), Q3b (lime packstone with skeletal sands), and Q3a (oyster, intraclast floatstone with packstone matrix) are present in the subsurface of this tree island (Figure 2, Appendix II). The predominantly quartz-sand unit that extends down from about 10 ft depth below the top of peat surface was designated as the Pinecrest Sand Member of the Tamiami Formation.

The differences in thickness and elevation of the Q units and their boundaries across the tree island suggest that some topographic relief was constructed by sediment deposition or erosion during the intervening subaerial exposures. In Figure 2, the subsurface stratigraphy shows a slightly higher elevation of the Pinecrest Sand Member below the tree island (cores 3AS3-GW3 and 3AS3-GW4) than off the tree island (cores 3AS3-GW1 and 3AS3-GW2). This on-island elevation anomaly seems to persist throughout subsequent carbonate deposition at core site 3AS3-GW4 and to a lesser extent at 3AS3-GW3. The northern "head" of the tree island has remained a topographic high from the time of the underlying quartz sand deposition, through the intermittent limestone deposition, and even to the most recent organic sediment deposition.

Stratigraphy of Tree Island 3BS1 Cores

All five Q units were delineated by examination of the limestone section in cores from Tree Island 3BS1, and these units are correlative across the site from the off-island coreholes (3BS1-GW1 and 3BS1-GW2) to the on-island coreholes (3BS1-GW3 and 3BS1-GW4) (Figure 3). At the 3BS1 site, the limestone section is considerably thicker (>28 ft) than to the west at the Tree Island 3AS3 site (~10 ft). In the deepest core boring (GW1), the base of the limestone was not penetrated at a maximum depth of 28 ft below sea level. Each Q unit has a distinct lithofacies: unit Q5 is peloidal packstone; unit Q4 is lime wackestone with subaerial exposure features; unit Q3b is lime wackestone and packstones with intraclast floatstone related to subaerial exposure; unit Q3a is lime wackestone-packstone, and alternating marine and freshwater limestone; and unit Q2 is marine lime packstone and bivalve floatstone.

The on-island/off-island correlation of the Q units at Tree Island 3BS1 is summarized in Figure 3. Q-unit thickness and their elevations are generally uniform across the tree island, but collectively they decrease in thickness upward. Deposition of limestone at Tree Island 3BS1 was associated with substantially greater accommodation space than at Tree Island 3AS3, as shown by the absence of the Pinecrest Sand Member at Tree Island 3BS1 (Figures 2 and 3).

The topography of the top of the bedrock at the Tree Island 3BS1 site has a 1-ft range; the local elevation at the GW4 core (head of the island) is about 1 ft higher than at the GW2 core (off island; Table 1). The greatest elevation change occurs in the thickness of the peat, with core GW4 having about a 4-ft higher elevation and about a 4-ft greater thickness than the off-island core borings.

Geophysical Logs

<u>Methods</u>

Borehole wireline log data (caliper, natural gamma, 16-inch and 64-inch normal resistivity, lateral resistivity, spontaneous potential, fluid resistivity, specific conductance, and temperature) were collected from each of the eight test coreholes. Core Laboratories, Inc., conducted hand-held spectral gamma-ray logging of the recovered core. The natural gamma-ray logs and the caliper logs were examined in detail. The natural gamma-ray log provides the best means of high-resolution correlation in the limestone units and the caliper log can be a good indicator of highly porous (vuggy porosity) zones. The formation of vuggy porosity is often influenced by original depositional texture and facies-specific diagenesis. In the following, the approximate positions of the Q-unit boundaries in the cores are correlated with the gamma-ray and caliper data, but recall that these boundaries have a vertical error, as recovery in each core run was positioned to fit at the top of the cored interval.

<u>Gamma-Ray Log</u>

The gamma-ray logs for the Tree-Island 3AS3 cores show a similar profile of generally higher intensity in the upper part and lower intensity in the lower part of the borehole (Figure 4). Higher values in the upper part correlate with the limestone units (~30-100 American Petroleum Institute [API] units), and the significantly lower in gamma-ray values correlate with the quartz sand deposits (~20-30 API units). Within the limestone units, the gamma-ray activity is highest in the lower units, especially in unit Q3a. Upward, within units Q4 and Q5, the gamma-ray activity decreases.

The gamma-ray logs from test coreholes on Tree Island 3BS1 show a varied response across the transect shown in Figure 5. Unit Q2 (basal marine limestone) has relatively high gamma-ray activity. Units Q3a and Q3b show an upward decrease in gamma-ray activity, except at test corehole GW-4, in which the units overall neither decrease nor increase upward. A slight increase in gamma-ray activity occurs from unit Q4 to Q5, although the strength of the gamma ray signal is highly variable.

There is a surprisingly variation in distinct gamma-ray signature over a relatively short horizontal distance at each site. This heterogeneity may be related to topographic differences controlling the duration of subaerial exposure and associated meteoric diagenesis, or perhaps the preservation of the exposure horizon at the tops of Q units (and associated higher gamma-ray activity) during subsequent marine transgressions.

<u>Caliper Log</u>

The caliper logs revealed several substantial voids (intervals of relatively large borehole diameter) that occur in the limestone sections of the boreholes at Tree Island 3AS3 (Figure 6). The off-island core site 3AS3-GW1 has open voids in unit Q3a, and off-island core site 3AS3-GW2 has open voids in units Q3a and Q3b. On-island, core sites 3AS3-GW3 and 3AS3-GW4 have borehole voids in unit Q4, near the top of the limestone and immediately beneath the peat.

The limestone sections at Tree Island 3BS1 show numerous voids of varying sizes, which are likely related to vuggy, highly dissolved, or poorly cemented rock fabric (Figure 7). Off-island boreholes (3BS1-GW1 and 3BS1-GW2) show voids in units Q2, Q3a, Q3b, and Q4. Unit Q5 contains a thin void in 3BS1-GW1 that was not evident in 3BS1-GW2. On-island cores (3BS1-GW3 and 3BS1-GW4) show a distinct void in the lower part of unit Q3a and a substantial void in unit Q4. Unit Q5 in 3BS1-GW3 shows an exceptionally large void, likely related to the extreme vuggy nature of the peloidal limestone. Unit Q5 was not recorded in the 3BS1-GW4 borehole.

Hand-Held Spectral Gamma-Ray Log Data

Core Laboratories, Inc., conducted spectral gamma-ray measurements on the recovered core samples. These hand-held gamma-ray measurements can sometimes be useful in matching the recovered core to the borehole logs, providing better depth positioning of the core pieces. In addition, the spectral gamma-ray data can help identify and confirm major subaerial exposure horizons.

In this study, hand-held data were compared to borehole data to help refine the depth position of the recovered core. This comparison was of limited use, primarily because the natural gamma-ray activity is varied on a very high frequency; therefore, the correlation remained uncertain and nonunique. In addition, the relatively low concentration of the spectral components precluded standard comparison plots indicative of redox potential or source lithology (potassium-uranium-thorium ratio charts or KUT ratio charts [Schlumberger, 1984]). Another limiting factor was the poor recovery of core, resulting in many sampling gaps (Appendix IV).

The occurrence and co-occurrence of the spectral gamma-ray data (potassium, uranium, and thorium) were also examined with respect to the core samples recovered (Appendix IV, Table 2).

Co-occurrence measures overlapping spectral components; for example, in the 3AS3-GW1 core (Table 2), at one depth there was one measurement of potassium that overlapped with a uranium measurement (or 9.1% of the 11 occurrences of potassium), and at five depths potassium overlapped with thorium (or 45.5% of the 11 occurrences of potassium). Several subaerial discontinuities in the core are correlative with co-occurrences of the spectral parameters. However, the nature of the spectral signature is less straightforward. The co-occurrence of spectral parameters, summarized for each core (Table 2), shows an inconsistent pattern with respect to the overlapping spectral components, which has potential to “fingerprint” subaerial discontinuities. This inconsistency is probably due to the different types of subaerial exposure horizons and their differing preservation status during subsequent marine transgression. For example, the duration of subaerial exposure, the type and amount of detrital mineral input relative to location and topography, and the amount of diagenesis of certain detrital minerals all can vary. Thus, the spectral gamma-ray dataset is of limited use for identification or confirmation of subaerial discontinuities observed in the core record.

PERMEABILITY OF THE TREE ISLAND CORES

Methods

Core samples from eight borings were selected and analyzed for whole-core permeability by Core Laboratories, Inc. The full-diameter (2-in) pieces were measured (using air flow) for permeability in two horizontal directions and one vertical direction while in a Hassler rubber sleeve. Porosity was determined using a helium pycnometer. The unconsolidated quartz-sand rich sediments recovered beneath Tree Island 3AS3 were measured for permeability using a plastic-sleeve technique at Core Laboratories, Inc. Results of 36 measurements from Tree Island 3AS3 are summarized in Figure 8.

Permeability of Limestone Units

For the Tree Island 3AS3 cores, 14 samples from the limestone units provided reliable permeability data (summarized in Figure 8). The permeability is highly variable, and likely related to differences in lithofacies type and degree of subaerial diagenesis. The higher permeability values appear to be related to lithofacies that have a relatively low percentage of lime mud (for example, micrite), a relatively high percentage of carbonate grains, and have undergone pervasive diagenetic leaching of skeletal grains. The moldic and vuggy porosity formed in these carbonate-grain-rich lithofacies (wackestone, packstone, and grainstone) produces extremely high effective porosity and permeability often in excess of 1 Darcy. Conversely, the lithofacies rich in lime mud (for example, micrite associated with mudstone and wackestone depositional textures) are often dense and well cemented with very low effective porosity. Furthermore, the formation of well-cemented subaerial exposure horizons (calcrete and soil breccias) may also generate intervals with very low permeability.

Tree Island 3BS1 has 27 samples with reliable permeability data (summarized in Figure 9). Similar to the 3AS3 core samples, a wide range of permeabilities was recorded in 3BS1 cores. The moldic and vuggy lithofacies produced extremely high permeabilities, usually in excess of 1 Darcy, and some in excess of 5 Darcies. The more moderate permeability values appear to be associated with the finer grained, well-cemented, mud-rich (micrite-rich) lithofacies; subaerial exposure horizons; and well-sorted, fine, skeletal-sand lithofacies lacking moldic or vuggy porosity.

The relationship of horizontal to vertical permeability in the two study areas indicates an anisotropic pore structure. In the 3BS1 core data, nearly half (11/23) of the measurements with both vertical and horizontal permeability have a greater vertical than horizontal value (see Figure 9). Likewise, the 3AS3 core data show a split horizontal-vertical preference in permeability (7 of 13 measurements). The higher vertical permeabilities could be related to semivertical dissolution features, such as solution-enlarged root molds, desiccation cracks, and burrows.

The presence of well-developed calcrete horizons and dense, well-cemented soil breccias within or at the Q-unit bounding surfaces would probably restrict direct vertical exchange of ground water. The competency and lateral continuity of these low-permeability units are unknown at this site, but are likely an important component in the vertical exchange of fluids.

Permeability of Underlying Siliciclastics at the 3AS3 Tree Island

The permeability of these quartz sands and mixed carbonates is generally in the moderate (200-500 md) and high (>500 md) range, as shown in Figure 8. These values are generally consistent with unconsolidated mixed sand- and mud-sized material. However, because the packing of grains may have been rearranged during shipping of the core samples to the lab, it is possible that the permeability measurements are not representative of in-situ conditions (S. Krupa, South Florida Water Management District, oral commun., 2001). The mud content generally controls the amount of permeability in samples of this type. The relatively permeable nature of these siliciclastic sediments may provide a shallow source of ground water to this tree island system. The amount of hydraulic communication and ease of vertical exchange is probably dictated by the lateral continuity of the low-permeability mud-rich lithofacies (mudstone, calcretes) in the overlying limestone section.

STRATIGRAPHIC ANOMALIES AND KEY HYDROGEOLOGIC FEATURES

Several subtle differences occur in lithofacies and topography between the on-island and off-island subsurface geologic records:

(1) At both tree islands, the elevation of the top of the limestone bedrock is elevated at the head of the tree islands relative to one or both of the off-island core sites and the core sites at the tail of the tree islands (Figures 2 and 3; Table 1). The elevation of limestone bedrock at the head of Tree Island 3AS3 is at least 4.3 ft higher than either off-island core site and 5.3 ft higher than the core site at the tail of the tree island (Table 1). The elevation of limestone bedrock at the head of Tree Island 3BS1 is at least 0.6 ft higher than either off-island core site and 0.6 ft higher than the core site at the tail of the tree island (Table 1). This higher elevation of limestone bedrock beneath the heads of the tree islands may have produced a different hydroperiod and habitat favorable to certain vegetation types, serving as a "seed" for the growth of the tree island. The thicker organic sediment at the head of Tree Island 3BS1 (Table 1) may indicate either earlier plant colonization and more rapid peat accumulation, or better peat preservation relative to the off-island sites. A complete probe mapping of the top-of-limestone surface would better address the hypothesis that a relatively high elevation of the top of the limestone-bedrock at the head of each tree island served as a point for tree island nucleation. The problem is that the number of measurements of bedrock and peat elevations at each tree island is only four, and the elevation of the top of the karst bedrock surface could be highly irregular, requiring many data points to confirm the hypothesis above.

(2) At Tree Island 3AS3, the elevation of the top of the Q5 unit is highest at the 3AS3-GW4 core site (head of the tree island), and the Q5 unit is more than twice as thick at the 3AS3-GW4 core site relative to its occurrence in the off-island 3AS3-GW1 core site (Q5 unit is missing at 3AS3-GW2 and 3AS3-GW3, Figure 2). At the 3BS1 tree island, the Q5 unit occurs at all four test coreholes, and the thinnest interval of the Q5 unit is at the head of the tree island (Figure 3).

(3) An examination of the recovered core samples and the caliper logs suggest that the elevated limestone beneath the tree islands may have a preferentially more porous framework relative to

limestone beneath the adjacent areas. If confirmed, this may provide a better ground-water-to-surface-water connection between the underlying formations and the tree island system, allowing for improved sustenance. The slightly elevated island foundation may have also been more heavily leached by vadose-zone processes relative to the off-island limestone, and earlier vegetation colonization may have aided the more rapid dissolution (with organic acids) of the underlying limestone.

(4) The anisotropic nature of permeability in the limestone beneath and adjacent to the tree islands suggests that ground water has the potential to move preferentially either vertically or horizontally, depending on local physical properties of the aquifer. Any vertical exchange with surface water would be dependent on the competency of the low-permeability subaerial exposure horizons and their ability to act as an aquiclude in the uppermost part of the limestone aquifer.

(5) Given that the elevation of the top of the limestone bedrock at the head of Tree Island 3AS3 is slightly higher than the surrounding upper surface of the peat (Table 1), and that the wetland peats have a lower hydraulic conductivity than the limestone bedrock of the Miami Limestone and Fort Thompson Formation (Sonenshein, 2001), it is possible that there is a head difference between the surface water of the wetlands and the underlying limestone bedrock. Thus, it is plausible that there may be greater interaction between surface water and ground water at this tree island.

REFERENCES

Bevier, C., and Krupa, S., 2001. Groundwater-surface water interaction in tree islands: Water Conservation Area 3 - Part 1: Phase 1 Well Installation. South Florida Water Management District, Technical Publication WS-4, 66 pp.

Cunningham, K.J., 2002. Application of ground-penetrating radar, digital optical borehole images, and core for characterization of porosity and paleokarst in the Biscayne aquifer, southeastern Florida, USA. Journal of Applied Geophysics, in press.

Dunham, R.J., 1962. Classification of carbonate rocks according to depositional texture. In, W.E. Ham, ed., Classification of carbonate rocks. Amer. Assoc. Petroleum Geologists Memoir 1, p. 108-121.

Folk, R.L., 1965. Some aspects of recrystallization in ancient limestones. In, L.C. Pray and R.C. Murray, eds., Dolomitization and limestone diagenesis, a symposium. Society of Economic Paleontologists and Mineralogists Spec. Pub. 13, p. 14-48.

Lucia, F.J., 1995. Rock-fabric/petrophysical classification of carbonate pore space for reservoir characterization. Amer. Assoc. Petroleum Geologists Bulletin, v. 79, p. 1275-1300.

Perkins, R.D., 1977. Depositional framework of Pleistocene rocks in South Florida, Part II: in, Enos, P., and Perkins, R.D., Quaternary Sedimentation in South Florida. Geological Soc. of America, Memoir 147, p. 131-198.

Powers, M.C., 1953. A new roundness scale for sedimentary particles. J. Sed. Petr., v. 23, p. 117-119.

Schlumberger Well Services, 1984. Log interpretation charts. 106 pp.

Sonenshein, R.S., 2001, Methods to quantify seepage beneath Levee 30, Miami-Dade County, Florida: U.S. Geological Survey Investigations Report 01-4074, 36 p.

Swanson, R.G., 1981. Sample Examination Manual. Amer. Assoc. Petroleum Geologists Methods in Exploration Series, 31 pp.

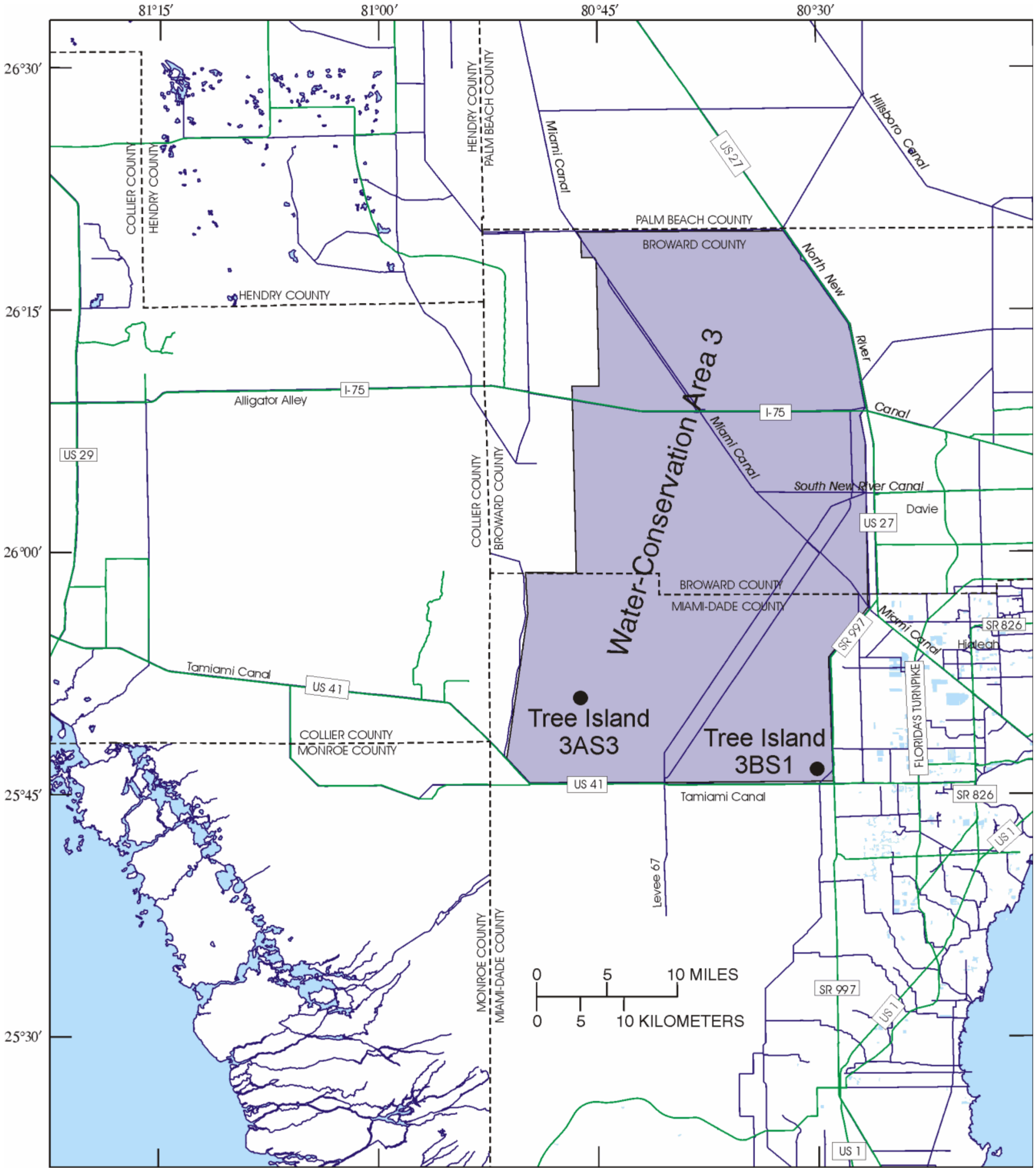


Figure 1. Location of Tree Islands 3AS3 and 3BS1.

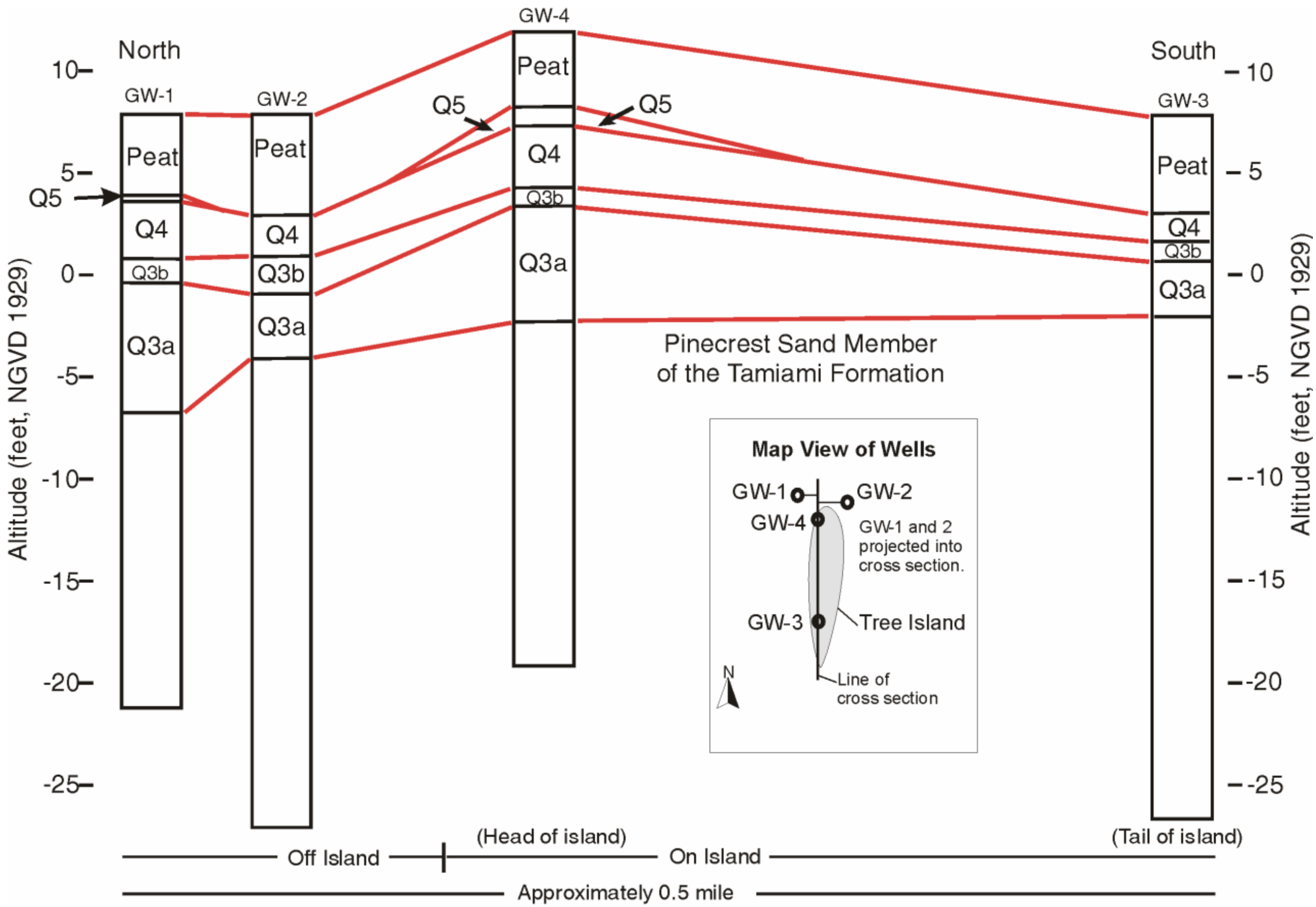


Figure 2. Stratigraphic cross section for Tree Island 3AS3.

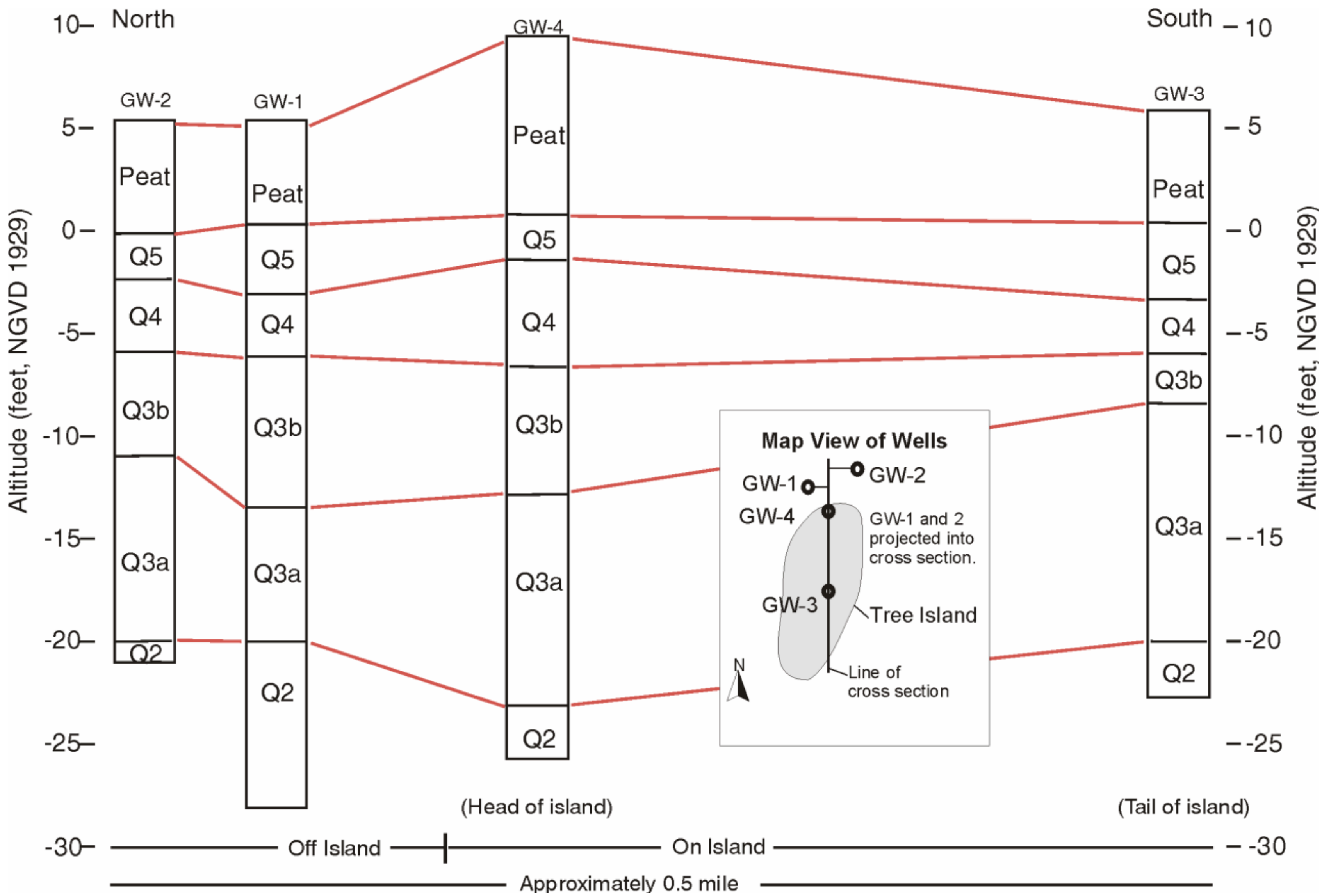


Figure 3. Stratigraphic cross section for Tree Island 3BS1.

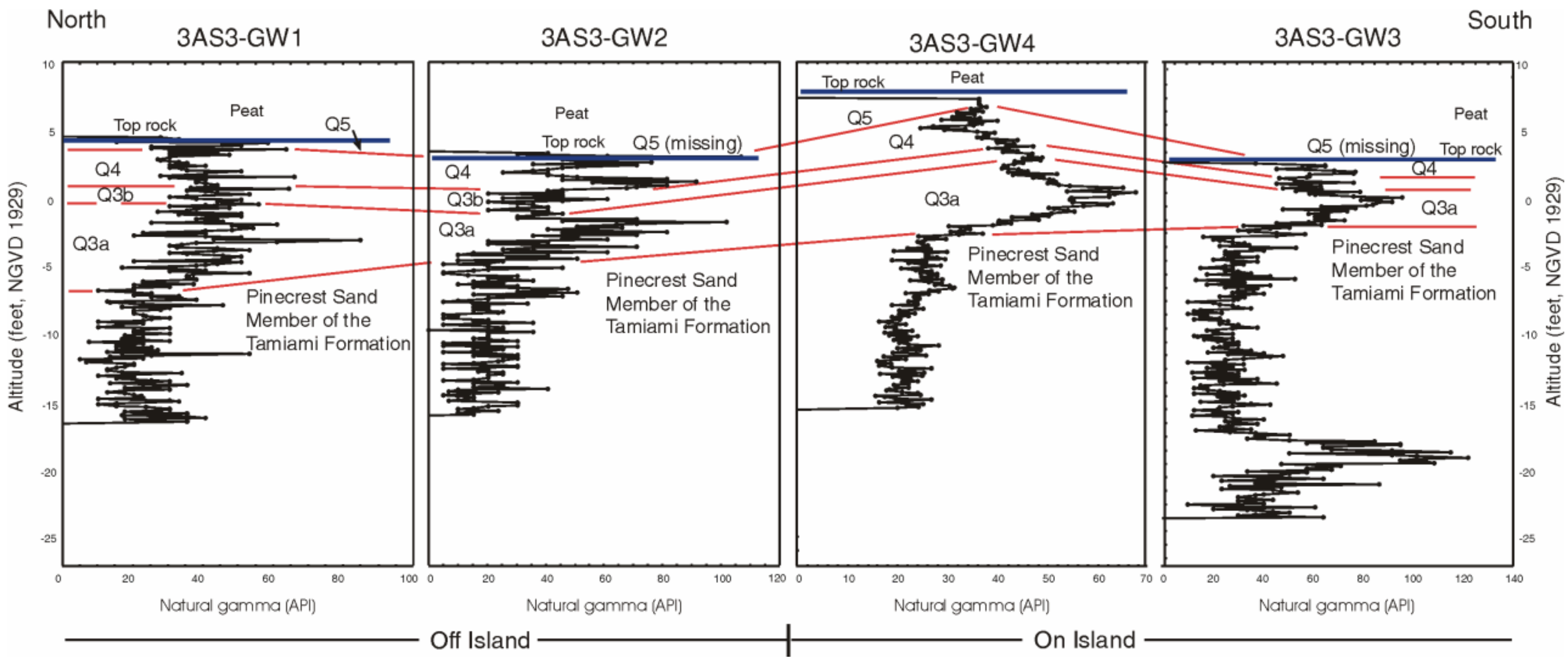


Figure 4. Natural gamma-ray logs and stratigraphic cross section for Tree Island 3AS3.

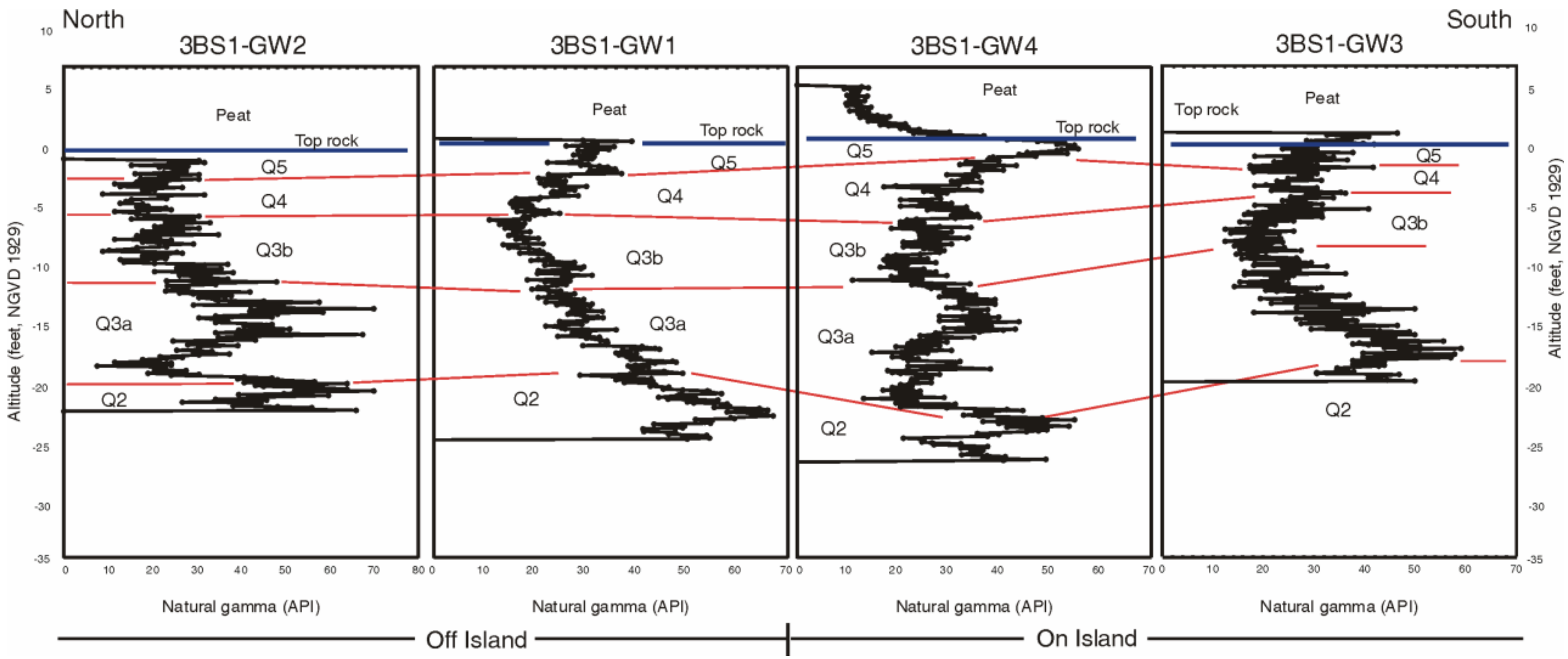


Figure 5. Natural gamma-ray logs and stratigraphic cross section for Tree Island 3BS1.

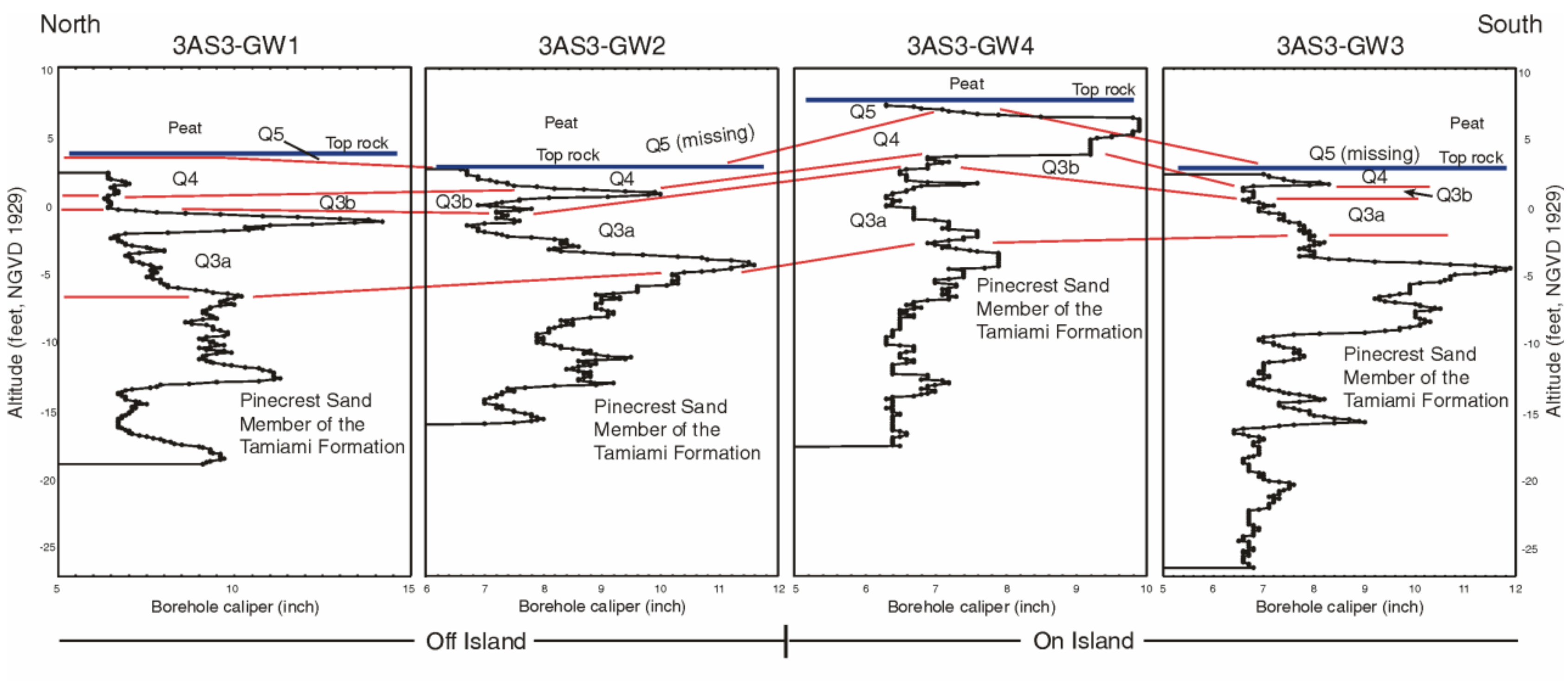


Figure 6. Caliper log and stratigraphic cross section for Tree Island 3AS3.

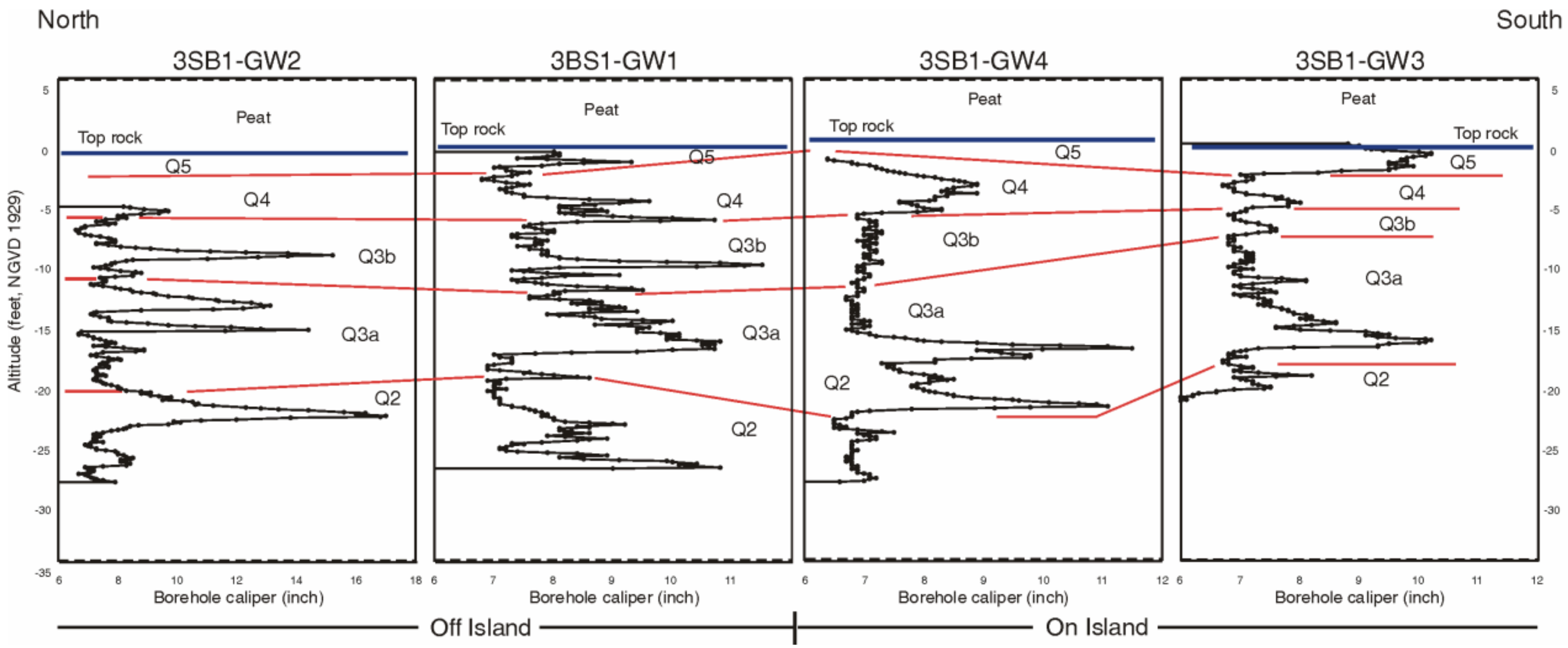
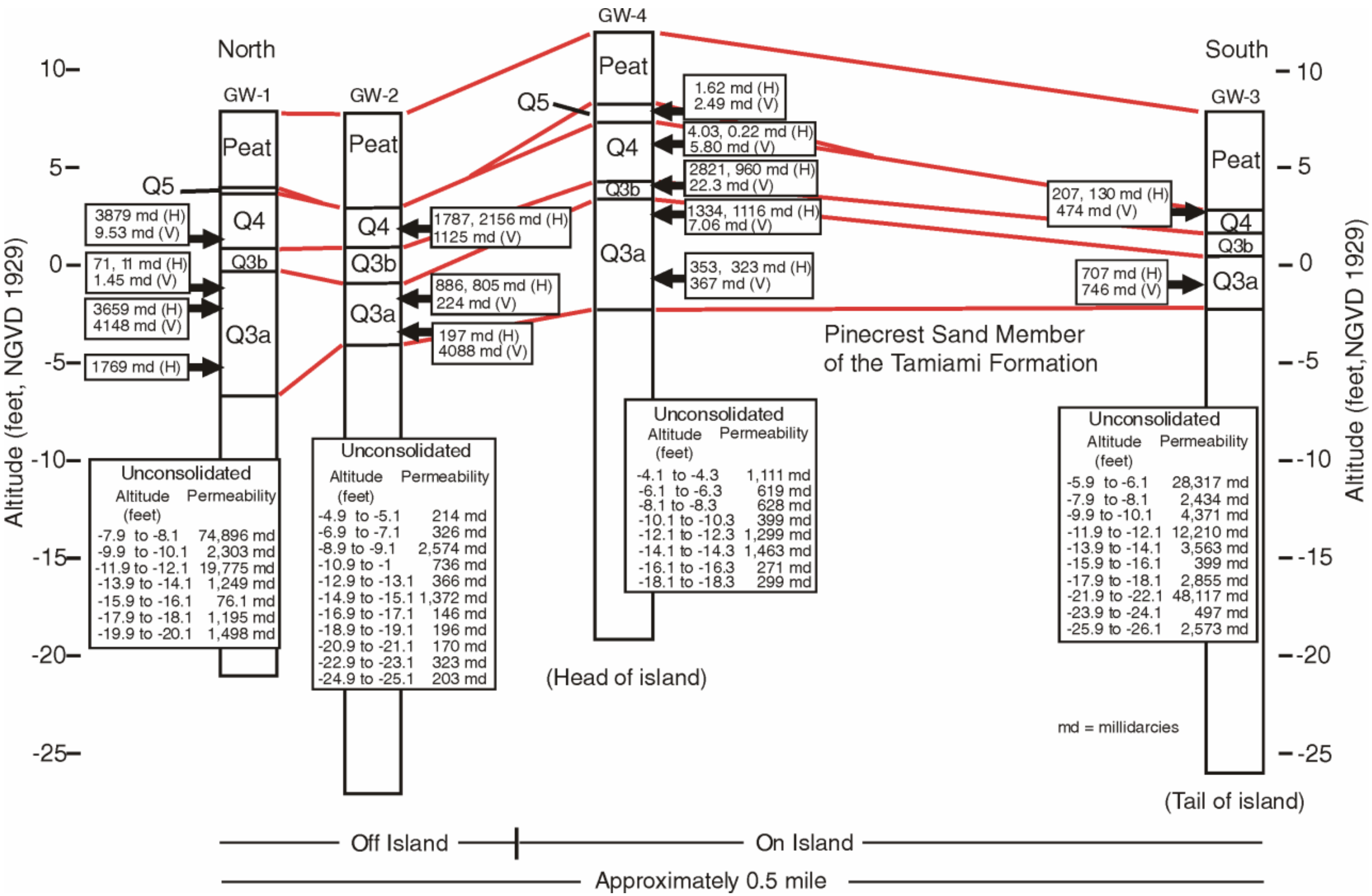


Figure 7. Caliper log and stratigraphic cross section for Tree Island 3BS1.



GW-1 Unconsolidated

Altitude (feet)	Permeability
-7.9 to -8.1	74,896 md
-9.9 to -10.1	2,303 md
-11.9 to -12.1	19,775 md
-13.9 to -14.1	1,249 md
-15.9 to -16.1	76.1 md
-17.9 to -18.1	1,195 md
-19.9 to -20.1	1,498 md

GW-2 Unconsolidated

Altitude (feet)	Permeability
-4.9 to -5.1	214 md
-6.9 to -7.1	326 md
-8.9 to -9.1	2,574 md
-10.9 to -1	736 md
-12.9 to -13.1	366 md
-14.9 to -15.1	1,372 md
-16.9 to -17.1	146 md
-18.9 to -19.1	196 md
-20.9 to -21.1	170 md
-22.9 to -23.1	323 md
-24.9 to -25.1	203 md

GW-4 Unconsolidated

Altitude (feet)	Permeability
-4.1 to -4.3	1,111 md
-6.1 to -6.3	619 md
-8.1 to -8.3	628 md
-10.1 to -10.3	399 md
-12.1 to -12.3	1,299 md
-14.1 to -14.3	1,463 md
-16.1 to -16.3	271 md
-18.1 to -18.3	299 md

GW-3 Unconsolidated

Altitude (feet)	Permeability
-5.9 to -6.1	28,317 md
-7.9 to -8.1	2,434 md
-9.9 to -10.1	4,371 md
-11.9 to -12.1	12,210 md
-13.9 to -14.1	3,563 md
-15.9 to -16.1	399 md
-17.9 to -18.1	2,855 md
-21.9 to -22.1	48,117 md
-23.9 to -24.1	497 md
-25.9 to -26.1	2,573 md

Figure 8. Stratigraphic cross section and permeability data for Tree Island 3AS3.

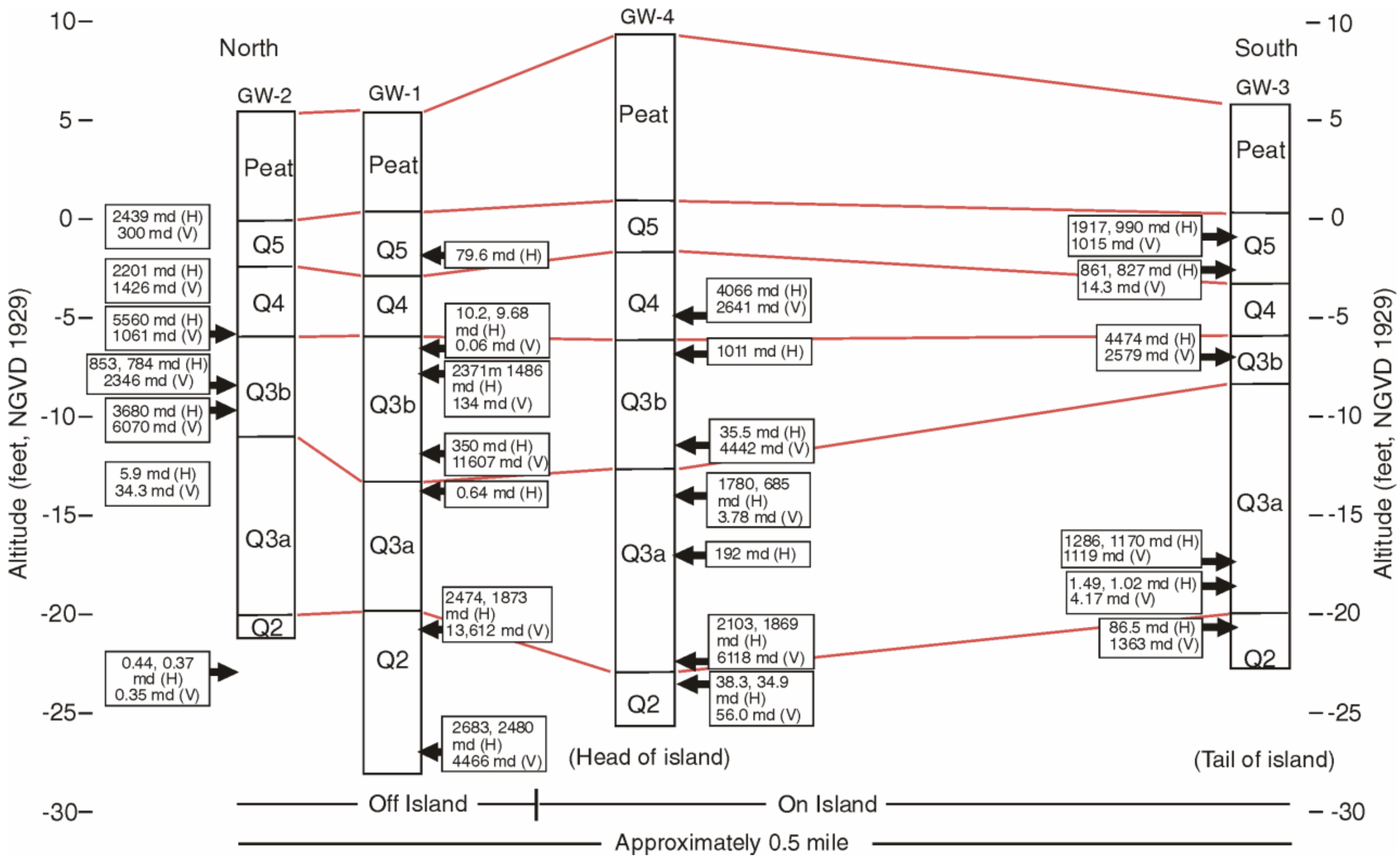


Figure 9. Stratigraphic cross section and permeability data for Tree Island 3BS1.

Table 1: Top of peat altitude and bedrock altitude at core locations.

Core Boring	**Location**	**Altitude of Top Peat (NGVD29 sea level datum, in feet)**	**Altitude of Top Bedrock (NGVD29 sea level datum, in feet)**
3AS3 GW1	off island	+7.89	+3.9
3AS3 GW2	off island	+7.86	+2.9
3AS3 GW3	on island	+7.90	+2.9
3AS3 GW4	on island	+11.74	+8.2
3BS1 GW1	off island	+5.34	+0.3
3BS1 GW2	off island	+5.36	-0.1
3BS1 GW3	on island	+5.82	+0.3
3BS1 GW4	on island	+9.43	+0.9

Table 2. Co-occurrence of spectral log parameters of core samples.

Co-occurrence measures overlapping spectral components, for example, in the 3AS3 GW1 core, at one depth there was one measurement of potassium that overlapped with a uranium measurement (or 9.1% of the 11 occurrences of potassium), and at five depths potassium overlapped with thorium (or 45.5% of the 11 occurrences of potassium). (n = total number of core measurements that had a measurable value for potassium, uranium, and thorium For example, in the 3AS3 GW1 core, there were 84 measurements attempted at different core depths, and multiplying by three for the three elemental parameters, there are 252 possible occurrences. The numbers given below are the number of occurrences for that element per 84 measurement sites on the core. Since there were many null measurements for each element, the total number of occurrences for each element is well below the maximum value of 84).

Spectral Parameter	**Total Number Occurrences**	**Co-Occurrence**		
		Potassium n / %	**Uranium n / %**	**Thorium n / %**
Core 3AS3 GW1	n = 84			
Potassium	11	---	1 / 9.1%	5 / 45.5%
Uranium	42	1 / 2.4%	---	4 / 9.5%
Thorium	21	5 / 23.8%	4 / 19.0%	---
Core 3AS3 GW2	n = 80			
Potassium	5	---	4 / 80.0%	1 / 20.0%
Uranium	40	4 / 10.0%	---	6 / 15.0%
Thorium	15	1 / 6.7%	6 / 40.0%	---
Core 3AS3 GW3	n = 74			
Potassium	0	---	---	---
Uranium	43	0 / 0%	---	7 / 16.3%
Thorium	18	0 / 0%	7 / 38.9%	---
Core 3AS3 GW4	n = 75			
Potassium	0	---	---	---
Uranium	38	0 / 0%	---	5 / 13.2%
Thorium	21	0 / 0%	5 / 23.8%	---
Core 3BS1 GW1	n = 86			
Potassium	5	---	1 / 20.0%	0 / 0%
Uranium	62	1 / 1.6%	---	30 / 48.4%
Thorium	39	0 / 0%	30 / 76.9%	---
Core 3BS1 GW2	n = 81			
Potassium	14	---	4 / 28.6%	1 / 7.1%
Uranium	48	4 / 8.3%	---	12 / 25.0%
Thorium	24	1 / 4.2%	12 / 50.0%	---
Core 3BS1 GW3	n = 93			
Potassium	8	---	3 / 37.5%	1 / 12.5%
Uranium	35	3 / 8.6%	---	9 / 25.7%
Thorium	40	1 / 2.5%	9 / 22.5%	---
Core 3BS1 GW4	n = 93			
Potassium	8	---	3 / 37.5%	1 / 12.5%
Uranium	35	3 / 8.6%	---	9 / 25.7%
Thorium	40	1 / 2.5%	9 / 22.5%	---

APPENDIX I

Thin-Section Descriptions and Photomicrographs

Thin-Section Description

Sample: **T-3AS3 - GW1 - 4.0**

Rock Type: Wackestone, lime-mud matrix with skeletal allochems, likely part of a calcrete horizon.

Grain Types

Carbonate:

65% lime mud: possibly originally peloids, now clotted;

20-25% skeletal: bivalve fragments, benthic foraminifers (Spirolina), echinoderm spines, possible ostracods, unidentified skeletal grains;

6-7% non-skeletal: some peloids visible, possible micritic root-mold linings;

Accessory Grains:

2-3% quartz sand: variable distribution, most 150-250 mm diameter, angular, low sphericity, few large grains up to 500 mm that are subrounded;

Comments: Orange staining of rock prevalent.

Diagenesis

-Rock cemented with blocky LMC (low magnesium calcite) spar in larger voids and molds of skeletal fragments.

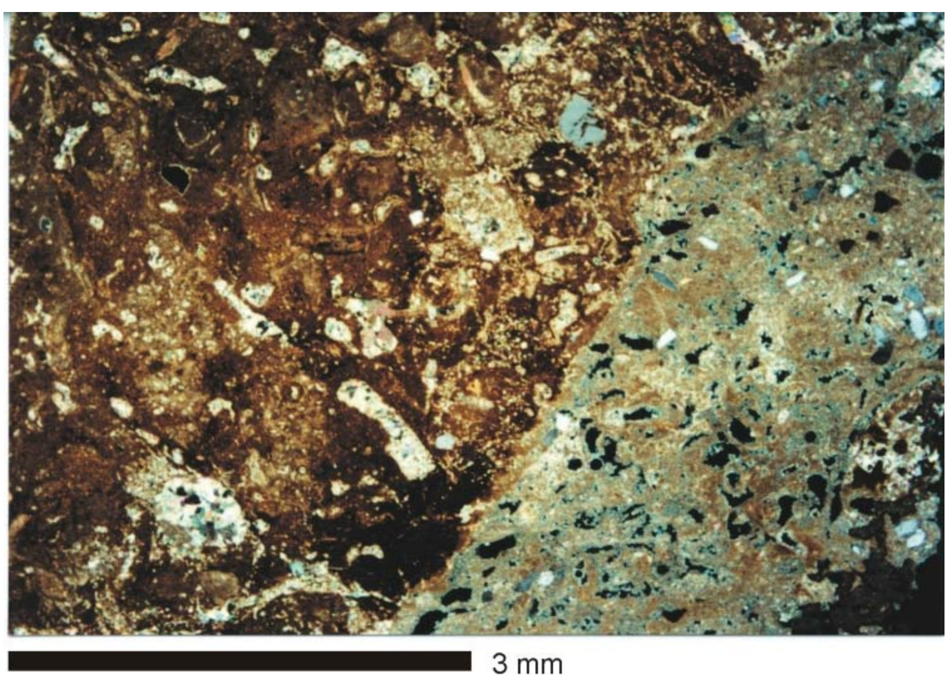
Porosity

-Generally low as micrite matrix occludes interparticle porosity, LMC fills skeletal molds.

-Total porosity estimated at 4-5%, low effective porosity.

Comments

-Marine limestone, relatively low-energy, lagoon setting. Subaerial exposure impact.



Thin-Section Description

Sample: **T-3AS3 - GW1 - 5.0**

Rock Type: Mudstone-wackestone, lime mud matrix with ~10% skeletal sand allochems.

Grain Types

Carbonate:

75% lime mud: dense, micritic cement, possibly originally peloids;

10% skeletal: thin-walled bivalve fragments, gastropod fragments, benthic foraminifers (Spirolina), possible ostracods, unidentified skeletal grains;

6-7% non-skeletal: some peloids visible, possible micritic root mold linings;

Accessory Grains:

trace% quartz sand: most 100-200 mm diameter, angular, low sphericity;

Comments: none

Diagenesis

-Some skeletal grains dissolved and replaced with LMC spar, some voids open w/o cement, overall well cemented, relatively dense.

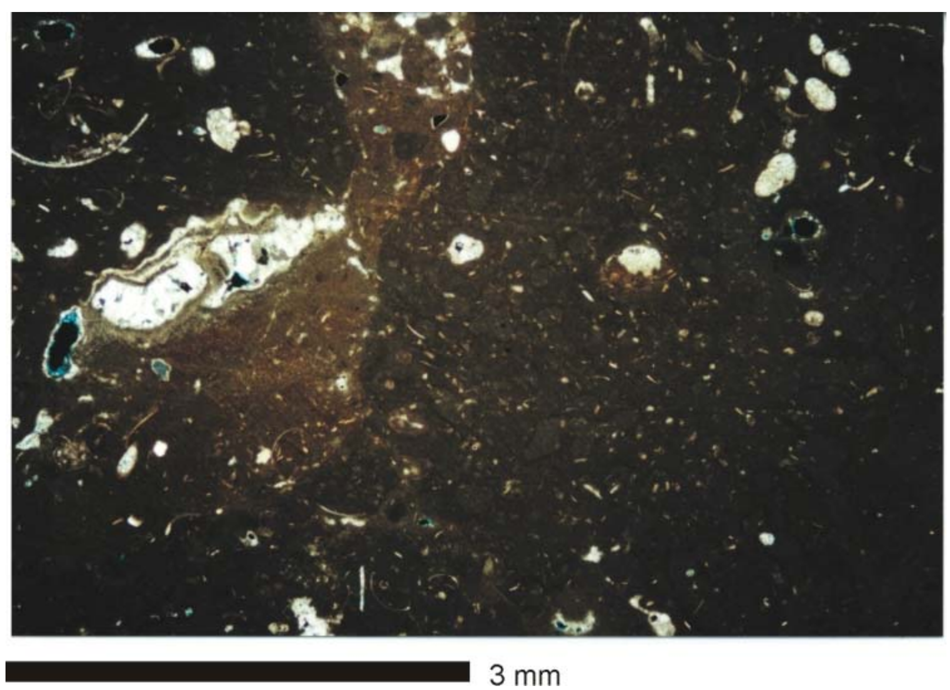
Porosity

-Generally low porosity, some minor moldic and micro-porosity.

-Total porosity estimated at 3-4%, low effective porosity.

Comments

-Depositional environment likely a restricted marine setting, relatively low energy.



Thin-Section Description

Sample: **T-3AS3 - GW1 - 6.0**

Rock Type: Mudstone, lime mud with vertical calcrete containing micritic, root-laminated calcrete and quartz sand.

Grain Types

Carbonate:

(left side) 90% lime mud: dense, micritic cement, possibly originally peloids;

(right side) 70% lime mud-micrite matrix associated with root molds;

(left side) 10% skeletal: bivalve fragments, benthic foraminifers (Spirolina, possible Archaias), ostracods, unidentified skeletal grains;

(right side) 15% skeletal; none visible;

Accessory Grains:

(right side) 15% quartz sand ranging from 100 mm to 1 mm, most subrounded to angular;

Comments: Section likely samples a vertical calcrete.

Diagenesis

-(left side) Most skeletal grains replaced with LMC spar, micritic cement in matrix, relatively dense.

-(right side) Possible root molds, partially infilled with LMC.

Porosity

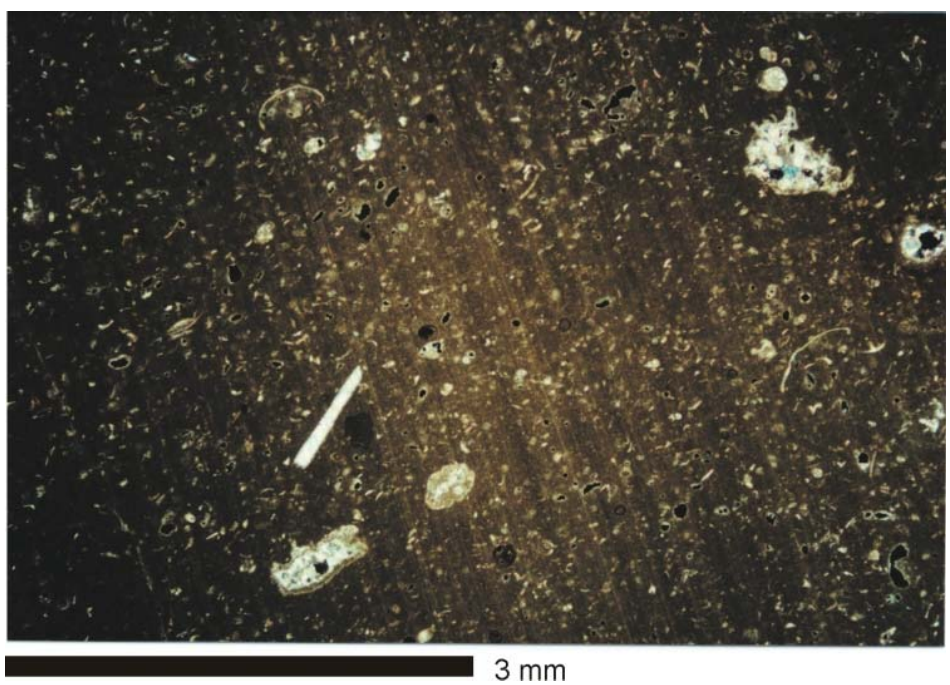
-(left side) 2-4% moldic porosity (note that preparation fractures not counted).

-(right side) 3-4% moldic porosity.

-Overall low effective porosity.

Comments

-Some fractures in thin-section likely related to drilling, they are open and show no infill along edges.



Thin-Section Description

Sample: **T-3AS3 - GW1 - 7.0**

Rock Type: Intraclast floatstone in a wackestone matrix with bivalve fragments and quartz sand.

Grain Types

Carbonate:

65% lime mud: dense, micritic cement, possibly originally peloids;

15% skeletal: bivalve fragments, benthic foraminifers;

10% non-skeletal: some peloids (200-300 mm), possible micritic root mold linings;

Accessory Grains:

10% quartz sand: most 100-600 mm diameter, most ~200 mm angular to subangular, low sphericity;

Comments: Possible micrite root molds, laminated.

Diagenesis

-LMC spar-filled voids, few voids still open w/o cement, overall moderately well cemented, relatively dense.

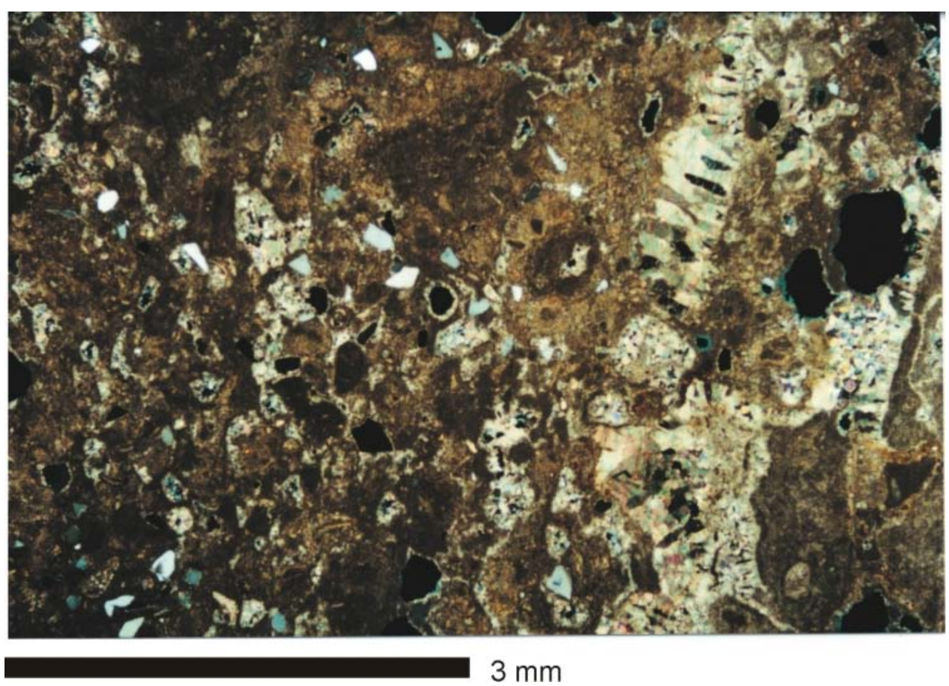
Porosity

-Mostly moldic porosity, some open pores may be quartz grains plucked during preparation.

-Total porosity estimated at 10%, moderate low effective porosity.

Comments

-Marine limestone, lime-mud rich altered by subaerial exposure processes.



3 mm

Thin-Section Description

Sample: **T-3AS3 - GW1 - 9.0**

Rock Type: Bivalve floatstone in a matrix (wackestone) of mixed lime mud and coarse quartz sand.

Grain Types

Carbonate:

50% lime mud: spatially variable amounts from 30-60% locally;

15% skeletal: spatially variable between 10-30%, large bivalve fragments, bryozoan fragments, benthic foraminifers;

Accessory Grains:

25% quartz sand: variable size, most 100-1200 mm diameter, smaller grains more angular, larger grains subrounded. Some areas have >50% quartz sand in lime mud matrix;

Comments: none

Diagenesis

-Some LMC block spar in larger voids, micrite cement in matrix.

Porosity

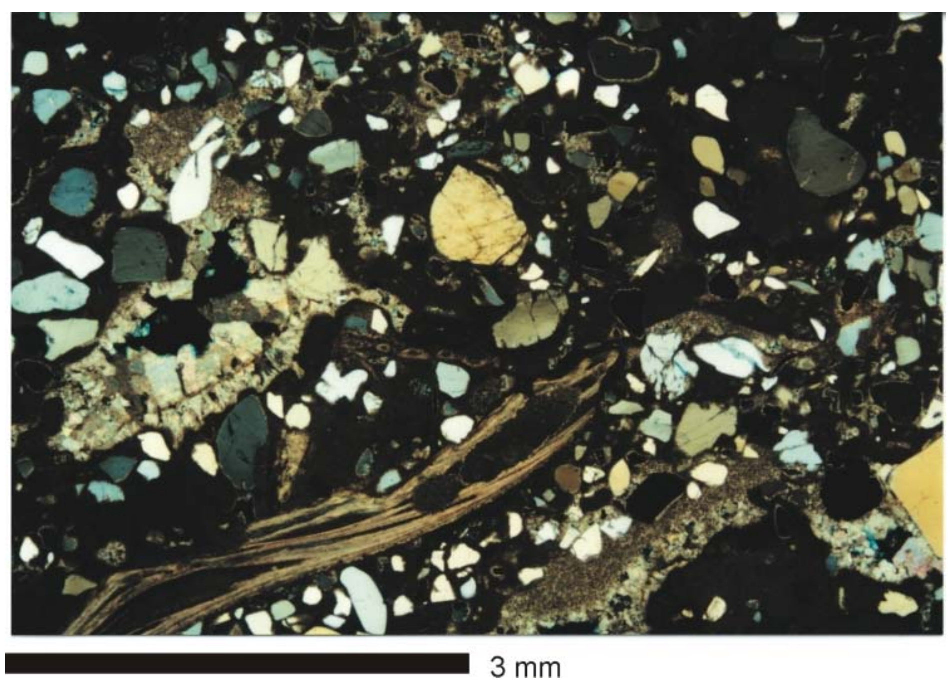
-Mostly moldic and interparticle porosity.

-Total porosity estimated at 10%, moderate low effective porosity.

Comments

-Matrix too thick to determine original composition or cement type.

-Marine limestone, semi-protected lagoon setting, mixed sand and lime mud.



Thin-Section Description

Sample: **T-3AS3 - GW1 - 10.0**

Rock Type: Bivalve floatstone in a matrix of mixed coarse quartz sand and lime mud.

Grain Types

Carbonate:

40-50% lime mud: possibly deposited as peloids;

25% skeletal: spatially variable between 10-30%, large bivalve fragments, benthic foraminifers (miliolids);

Accessory Grains:

20% quartz sand: variable size, range <100->500 mm diameter, most are in the 300 mm range, subangular to subrounded;

Comments: none

Diagenesis

-Many open voids likely molds related to skeletal dissolution.

-Some LMC block spar infill larger voids.

Porosity

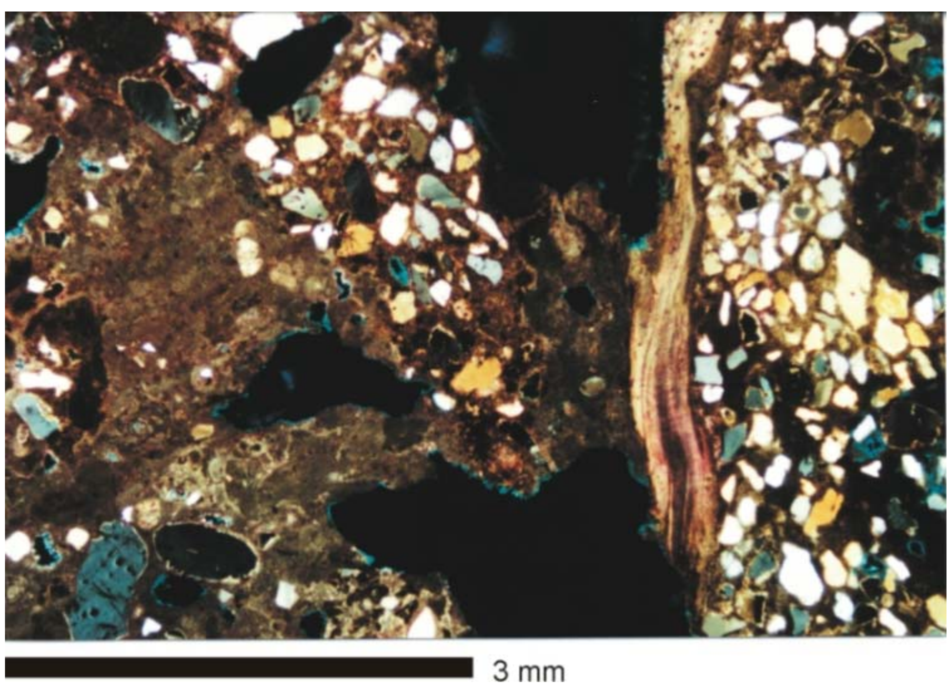
-Mostly moldic porosity associated with vugs.

-Total porosity estimated at 15%, moderate effective porosity.

Comments

-Lithology similar to thin-section from 3AS3-GW1-9.

-Marine limestone, semi-protected lagoon setting, mixed sand and lime mud.



Thin-Section Description

Sample: **T-3AS3 - GW1 - 12.0**

Rock Type: Peloid, root-mold lime wackestone with skeletal allochems and laminar micrite (calcrete).

Grain Types

Carbonate:
70% non-skeletal: clotted peloids, root-mold structures;
10-15?% lime mud: matrix, associated with clotted peloids and root molds;
10% skeletal: bivalve fragments, benthic foraminifers, gastropod fragments;
Accessory Grains:
4-5% quartz sand: range100-300 mm diameter, subangular, moderate sphericity;
Comments: none

Diagenesis

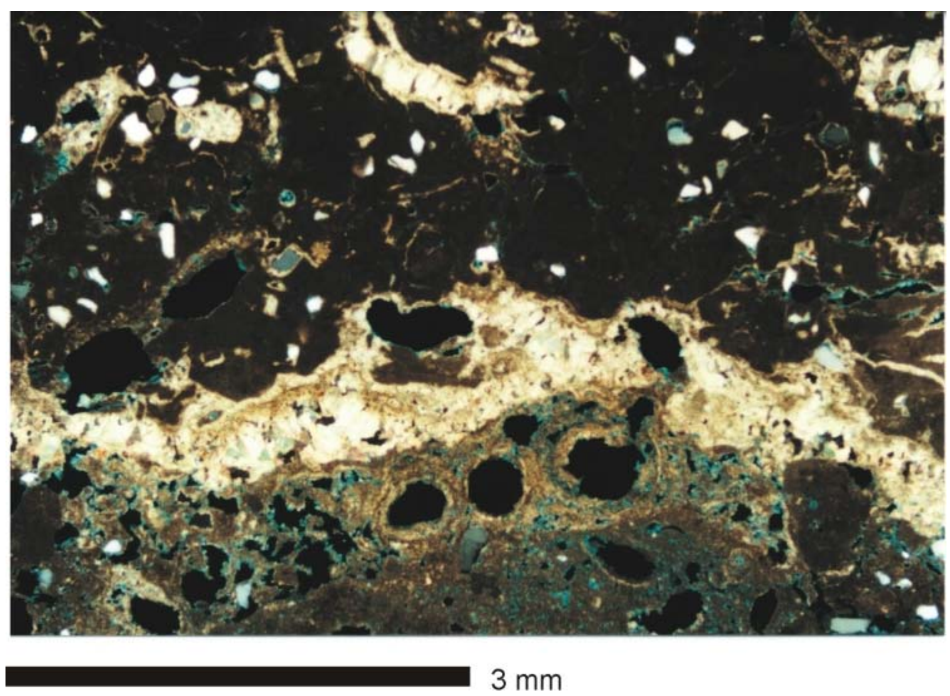
-Moldic dissolution, most skeletal allochems replaced with LMC spar.
-LMC spar cement, moderately-well cemented.

Porosity

-5-7% mainly moldic porosity related to root molds and skeletal allochems.
-Low effective porosity.

Comments

-Marine limestone with overprint of root penetration, calcrete, clotted peloids.



Thin-Section Description

Sample: **T-3AS3 - GW1 - 13.0**

Rock Type: Gastropod, bivalve floatstone in a matrix of mixed quartz sand and limemud/microspar.

Grain Types

Carbonate:

20% lime mud/microspar (<10 mm LMC crystals);

20% skeletal: large (>1-2 mm) gastropod fragments, bivalve fragments (2-3 mm);

Accessory Grains:

30% quartz sand: variable size, most 150-250 mm diameter, grains mostly angular, few larger grains up to 800 mm, subangular, moderate sphericity;

Comments: Possibility of carbonate intraclasts in section (1-2 mm long).

Diagenesis

-Some large vugs resulting from leached gastropods shells.

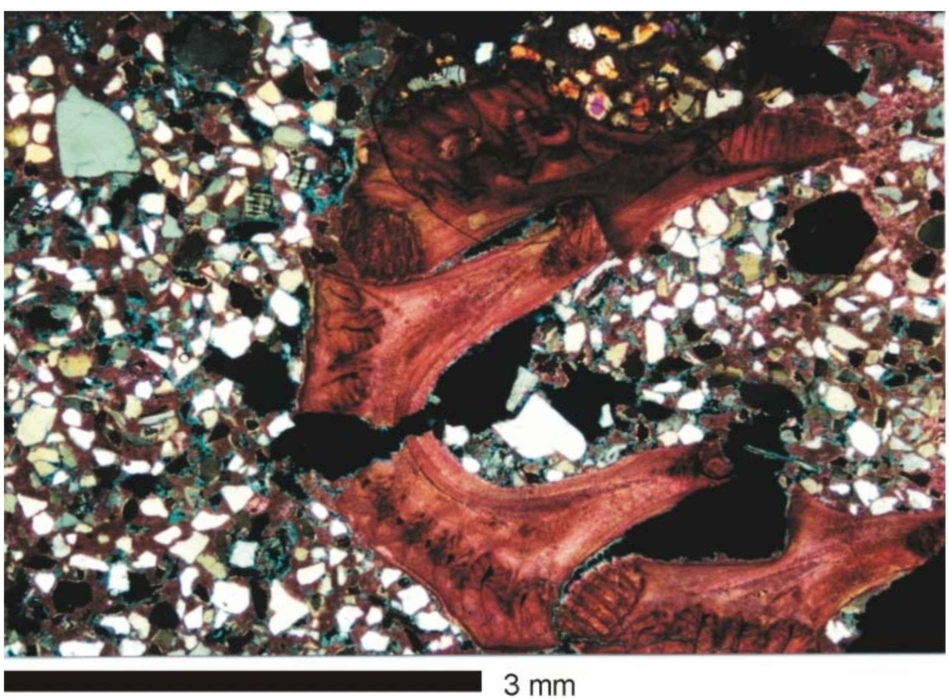
Porosity

-Mostly moldic porosity related to leached gastropod shells, and some interparticle porosity associated with matrix.

-Total porosity estimated at 30%, high effective porosity.

Comments

-Matrix is basically a sandstone with a carbonate (microspar) cement.



Thin-Section Description

Sample: **T-3AS3 - GW2 - 6.0**

Rock Type: Wackestone-packstone with peloids, benthic foraminifers, and root molds.

Grain Types

Carbonate:

35-40% lime mud: micrite and microspar dense;

30-35% skeletal: benthic foraminifers (miliolid, Spirolina, Archaias), bivalves, gastropods, unidentified skeletal grains;

5-7% non-skeletal: micritic root mold linings;

Accessory Grains:

3-5% quartz sand: most 100-200 mm diameter, angular to subangular, low sphericity;

Comments: Laminated root mold structures.

Diagenesis

-Some skeletal grains dissolved and replaced with LMC spar, many open w/o cement, overall well cemented, relatively dense.

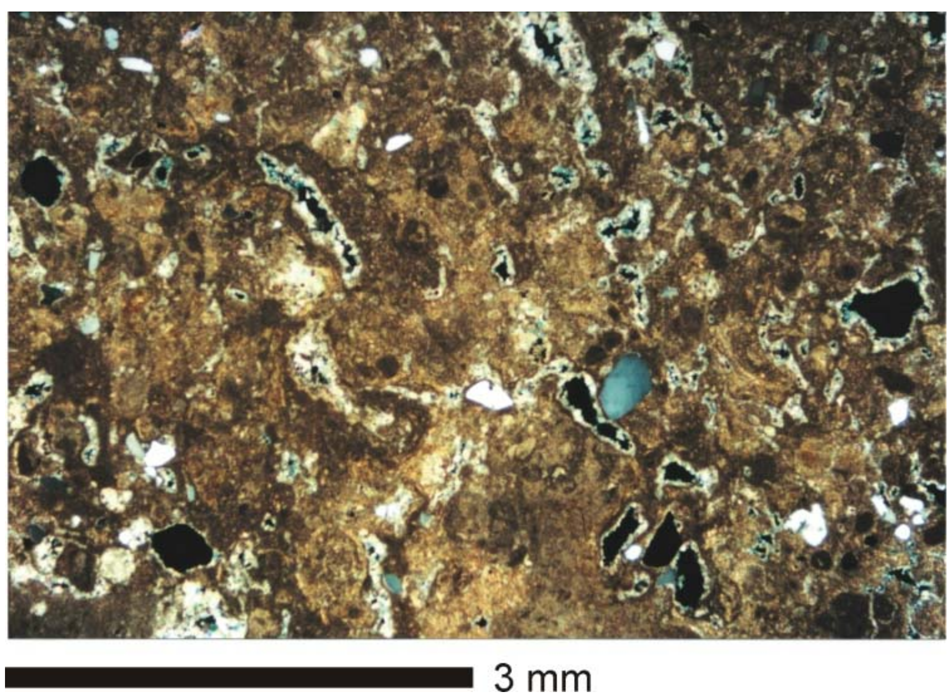
Porosity

-Mainly moldic porosity, some interparticle.

-Total porosity estimated at 15%, moderate effective porosity.

Comments

-Marine limestone, open lagoon sand shoal with modification from subaerial exposure processes.



Thin-Section Description

Sample: **T-3AS3 - GW2 - 9.5**

Rock Type: Bivalve floatstone in matrix of quartz sand and microspar mud.

Grain Types

Carbonate:

30% lime mud: micrite and microspar;

20% skeletal: large (1-2 mm) bivalve fragments, benthic foraminifers, unidentified skeletal grains;

Accessory Grains:

30% quartz sand: most 100-600 mm diameter, angular, low sphericity;

Comments: none

Diagenesis

-Microspar matrix as cement for rock, some LMC spar replacing larger shells.

Porosity

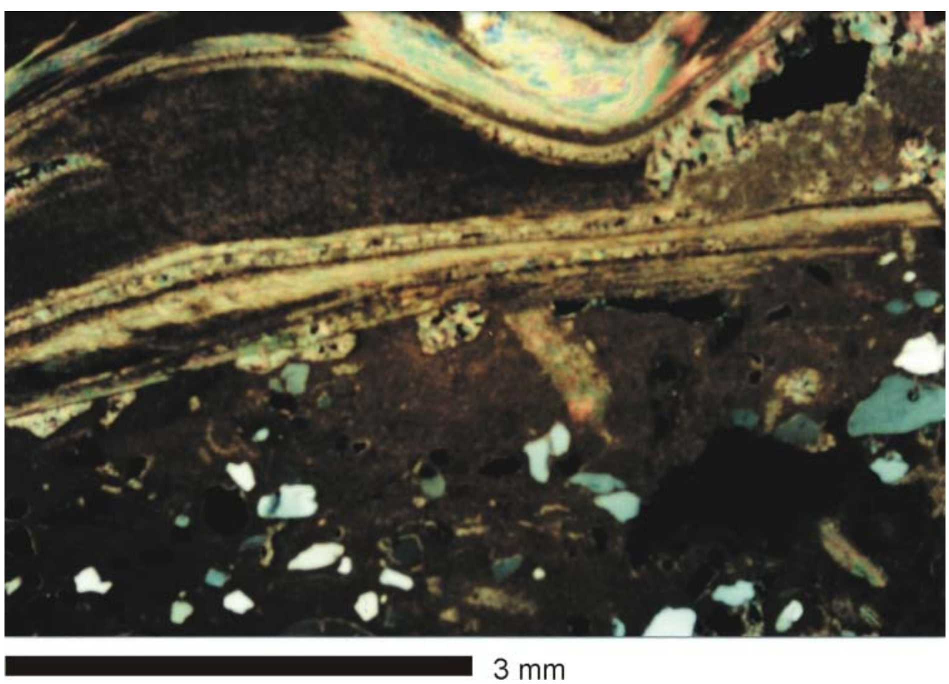
-Mainly moldic porosity, some interparticle porosity.

-Total porosity estimated at 20%, high effective porosity.

Comments

-Lithology similar to T-3AS3-GW1-13.0.

-Restricted marine, lagoon setting with abundant quartz sand likely reworked through bioturbation.



Thin-Section Description

Sample: **T-3AS3 - GW2 - 11.0**

Rock Type: Bivalve floatstone with a lime wackestone matrix containing abundant quartz sand and some skeletal allochems.

Grain Types

Carbonate:

25-30% lime mud: matrix;

20% skeletal: large bivalve fragments, echinoderm spine;

Accessory Grains:

30-40% quartz sand: range 150-600 mm diameter, subrounded, moderate sphericity;

Comments: none

Diagenesis

-Well cemented with micrite cement, very little moldic dissolution.

-Some LMC spar replacement.

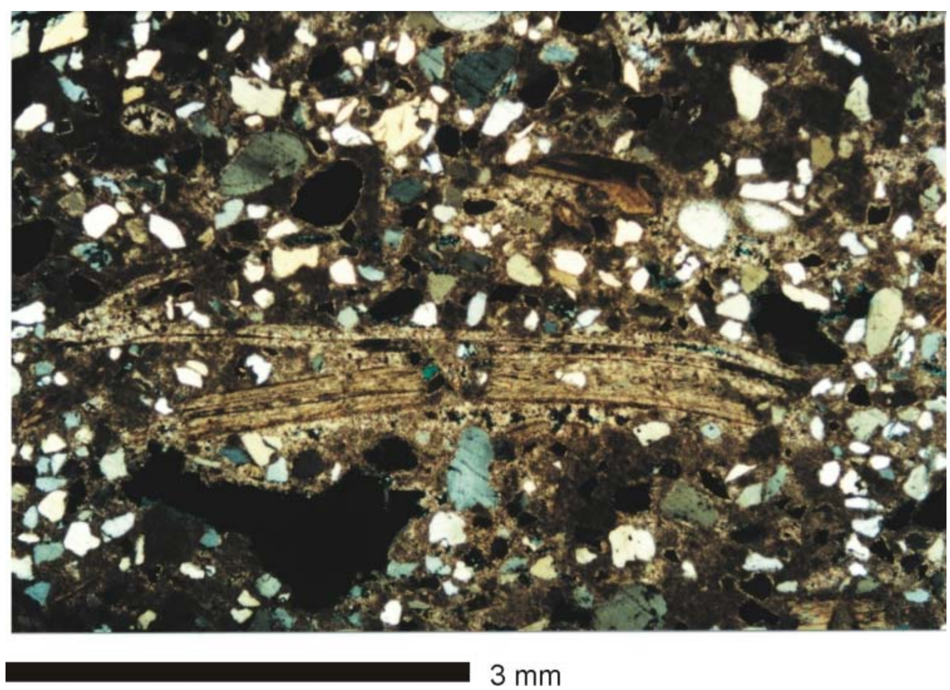
Porosity

-15-20% interparticle porosity.

-Moderate-high effective porosity.

Comments

-Marine limestone with abundant quartz sand, moderate energy lagoon sand shoal with lime mud.



Thin-Section Description

Sample: **T-3AS3 - GW3 - 5.0**

Rock Type: Lime mudstone with some skeletal sand allochems.

Grain Types

Carbonate:

85-90% lime mud: massive, matrix;

3-4% skeletal: ostracods, bivalve fragments, benthic foraminifers (Spirolina);

Accessory Grains:

1% quartz sand: range 75-200 mm diameter, angular, low sphericity;

Comments: none

Diagenesis

-Some skeletal dissolution and LMC spar replacement/infill.

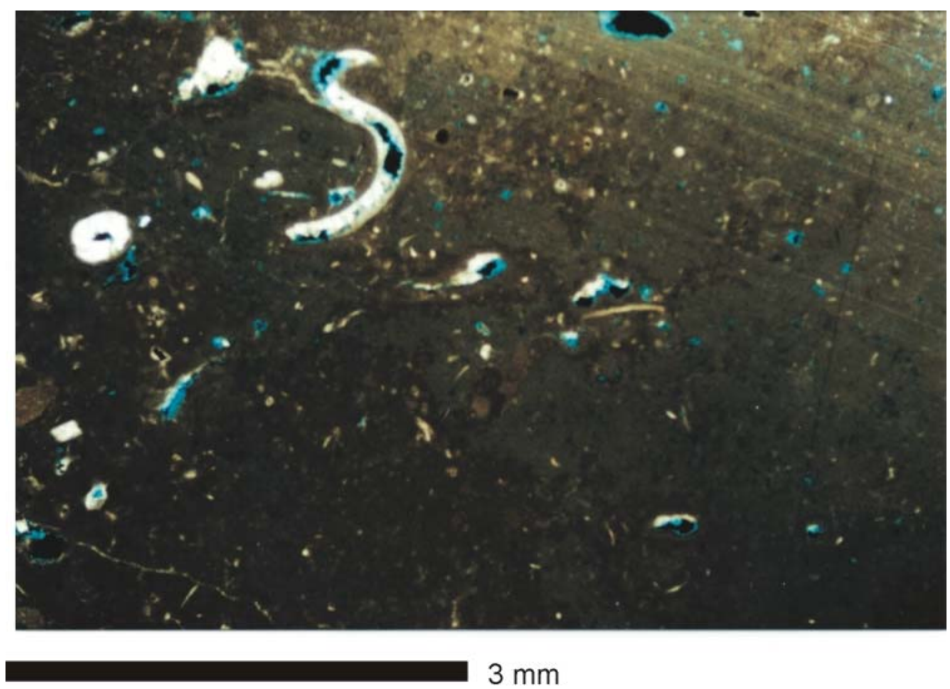
Porosity

-Total porosity estimated at 5-6% mainly moldic porosity.

-Low effective porosity.

Comments

-Marine limestone, relatively low energy lagoon setting, lime mud accumulation.



Thin-Section Description

Sample: **T-3AS3 - GW3 - 9.0**

Rock Type: Bivalve floatstone in a lime wackestone matrix with some quartz sand.

Grain Types

Carbonate:

45-50% lime mud: massive, matrix;

15-20% skeletal: large bivalve fragments (possible oyster);

Accessory Grains:

15-20% quartz sand: range100-300 mm diameter, most subangular, moderate sphericity, few grains >500 mm;

Comments: none

Diagenesis

-Some dissolution of skeletal allochems, some LMC spar replacement.

-Micritic cement.

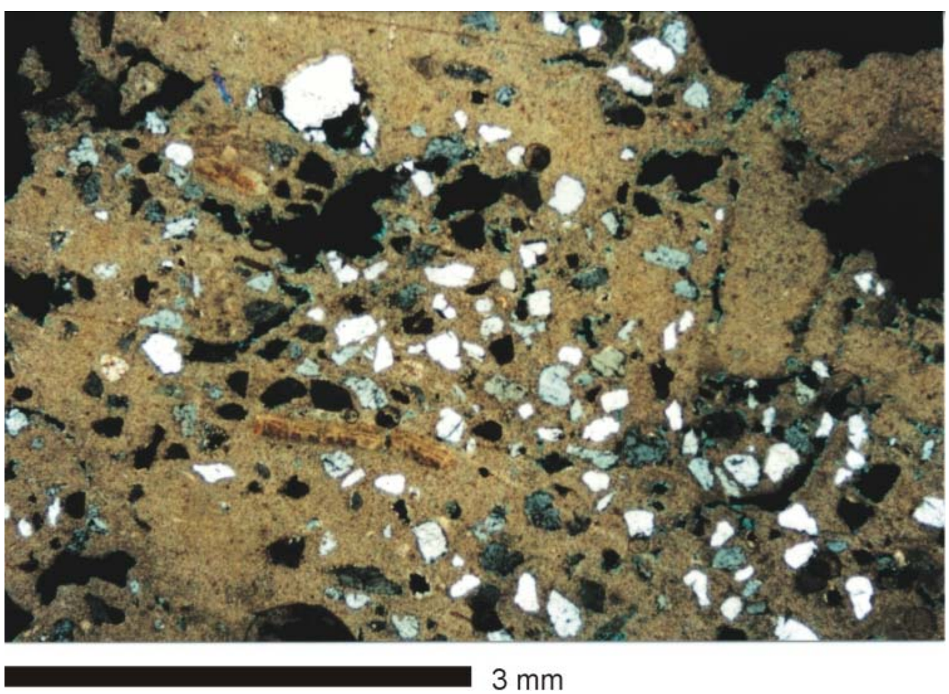
Porosity

-20% moldic and interparticle porosity.

-Moderate-high effective porosity.

Comments

-Semi-protected lagoon setting, lime mud with mollusk fragments.



Thin-Section Description

Sample: **T-3AS3 - GW4 - 4.0**

Rock Type: Bryozoan and bivalve floatstone with a peloid sand matrix (grainstone) and skeletal allochems.

Grain Types

Carbonate:

45% nonskeletal: peloid sand;

40% skeletal: large (>2 mm) bivalve and bryozoan fragments, benthic foraminifers (miliolid), Halimeda fragments;

Accessory Grains:

trace% quartz sand: range 50-100 mm diameter, subrounded, moderate sphericity;

Comments: none

Diagenesis

-Skeletal allochem dissolution and replacement with LMC spar.

-Abundant LMC spar cement.

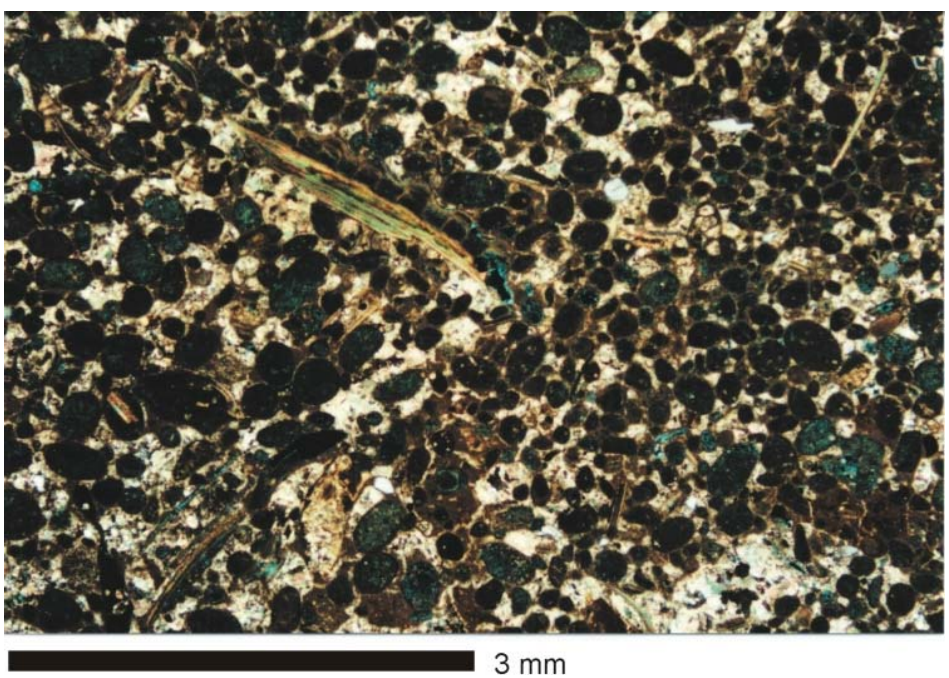
Porosity

-15% total porosity, mainly interparticle with some moldic and micro-porosity.

-Moderate effective porosity.

Comments

-Mixed peloid/skeletal sand shoal, low lime mud content, pore space filled with LMC spar cement.



Thin-Section Description

Sample: **T-3AS3 - GW4 - 5.0**

Rock Type: Lime mudstone/wackestone with some skeletal allochems.

Grain Types

Carbonate:

85% lime mud: massive matrix, some peloids visible in some areas associated with possible root penetration;

5% skeletal: ostracod, gastropod fragments, thin-walled bivalves;

Accessory Grains:

trace% quartz sand: range 50-100 mm diameter, subrounded, moderate-high sphericity;

Comments: none

Diagenesis

-Most skeletal allochems dissolved and replaced with LMC spar.

-Some possible root mold areas infilled with LMC.

Porosity

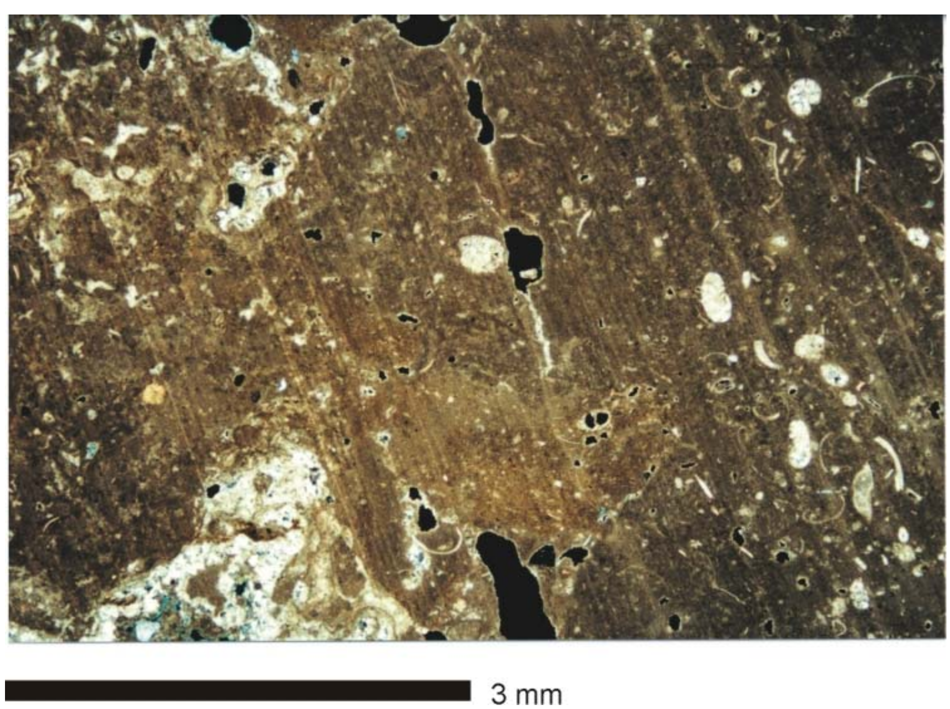
-Mainly moldic porosity at between 5-10% (not counting preparation fractures).

-Low effective porosity.

Comments

-Root molds modification uncertain, mostly undisturbed lime mudstone.

-Low-energy marine setting, protected mudbank or lagoon.



Thin-Section Description

Sample: **T-3AS3 - GW4 - 7.5**

Rock Type: Bivalve, benthic foraminifera floatstone in lime mud matrix (wackestone).

Grain Types

Carbonate:

50% lime mud: possibly peloids when deposited;

25-30% skeletal: large (1-2 mm) bivalve fragments, benthic foraminifers (Spirolina), gastropods, unidentified skeletal grains;

Accessory Grains:

1-2% quartz sand: 100-300 mm diameter, angular, low sphericity;

Comments: Possible root-mold structures.

Diagenesis

-Skeletal allochem dissolution, LMC spar replacing some benthic foraminifers and gastropods shells.

Porosity

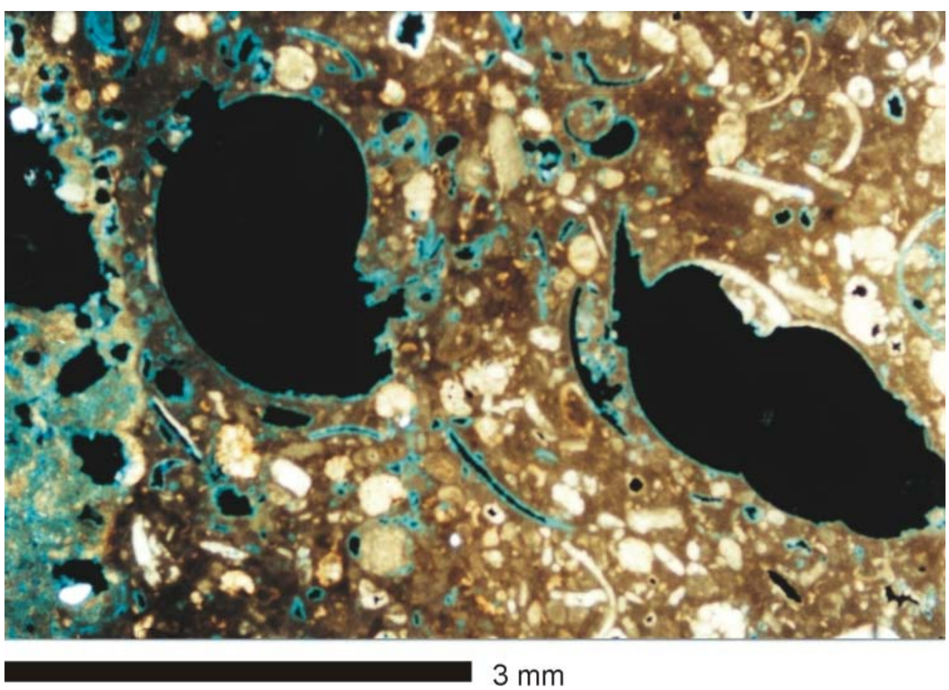
-Mainly moldic porosity after skeletal fragments, some interparticle porosity.

-Total porosity estimated at 10-15%, moderate-high effective porosity.

Comments

-Marine limestone from semi-restricted lagoon setting.

-Possible calcrete features (laminations) and subaerial exposure surface.



Thin-Section Description

Sample: **T-3AS3 - GW4 - 9.0**

Rock Type: Bivalve floatstone in lime mud and quartz sand matrix.

Grain Types

Carbonate:
(right side) 35-45% lime mud: micrite and microspar as matrix and cement;
(left side) 66-75% lime mud: micrite and microspar as matrix and cement;
(right side) <5% skeletal: possible bivalve fragments;
(left side) <5% skeletal: possible ostracod shells and one large oyster fragment, few smaller bivalve fragments;
Accessory Grains:
(right side) 60-70% quartz sand: range100-800 mm diameter, angular to subrounded, low sphericity;
(left side) 2-4%, 100-300 mm, subangular, few large grains >1mm;
Comments: Note left side has root molds and concentric root structures.

Diagenesis

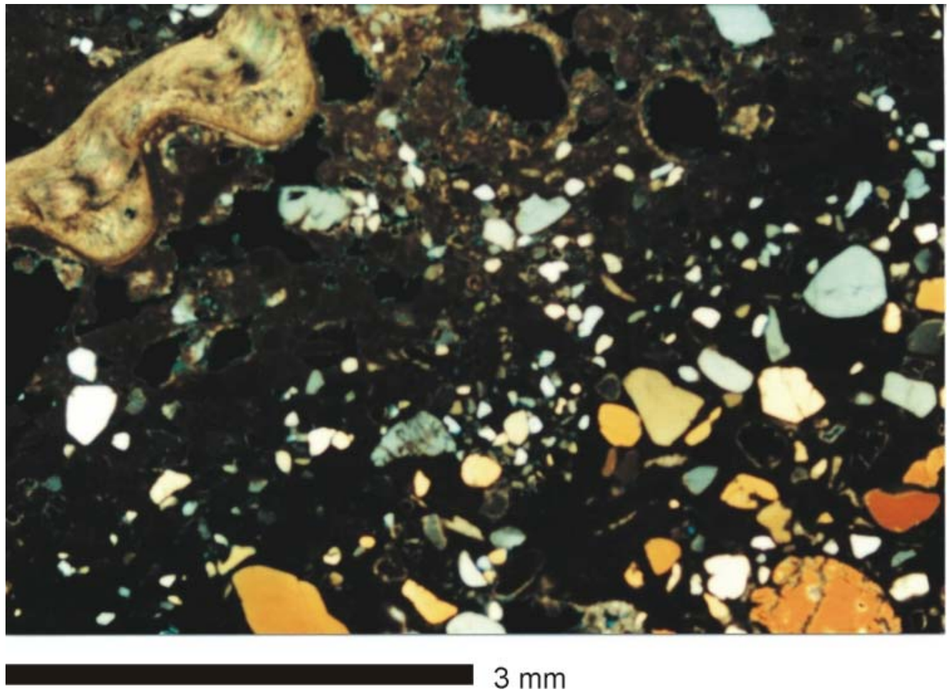
-(right side) Possible dissolution of skeletal allochems.
-(left side) Root mold features, micrite fabric.

Porosity

-(right side) Mainly moldic porosity after skeletal fragments, some interparticle porosity,
-Total porosity estimated at 15-20%, moderate-high effective porosity.
(left side) Root molds yield open voids,10-15% moldic porosity.

Comments

-Thin-section is too thick to identify features within the matrix.
-Marine limestone with subaerial exposure dissolution, calcrete.



Thin-Section Description

Sample: **T-3AS3 - GW4 - 11.0**

Rock Type: Lime wackestone with quartz sand, mollusc fragments and root molds.

Grain Types

Carbonate:

50% lime mud: lime mud with some micrite related to root structures;

10% skeletal: large gastropod shell, possible bryozoan, bivalve/ostracod;

Accessory Grains:

25% quartz sand: range100-400 mm diameter, angular to subrounded, low sphericity, few grains >800 mm;

Comments: none

Diagenesis

-Many open voids related to root penetration. Some concentrically laminated.

Porosity

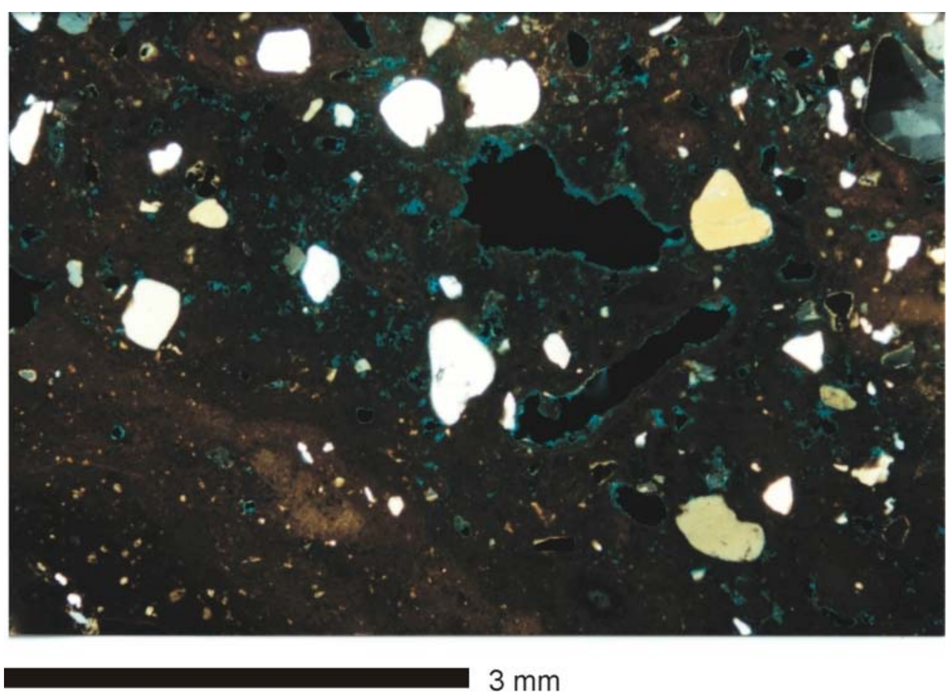
-Mainly moldic porosity related to root molds.

-Total porosity estimated at 15%, moderate-high effective porosity.

Comments

-Root molds and laminated calcrete suggestive of subaerial exposure horizon.

marine limestone with quartz sand, modified by subaerial exposure



Thin-Section Description

Sample: **T-3BS1 - GW1 - 6.5**

Rock Type: Peloid packstone, with some bivalve allochems.

Grain Types

Carbonate:
15% lime mud: matrix of microspar and lime mud;
5% skeletal: bivalve fragments, benthic foraminifers, green algae, possible ostracods, unidentified skeletal grains;
55% non-skeletal: peloids dominant, most 150-400 mm;
Accessory Grains:
1-2% quartz sand: most 150-250 mm diameter, angular, low sphericity;
Comments: none

Diagenesis

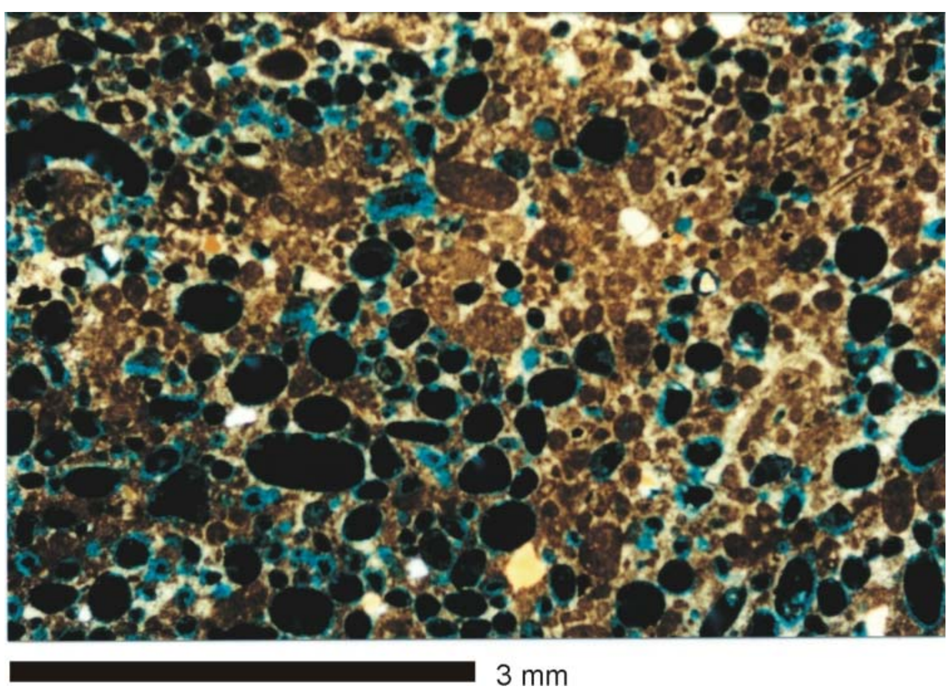
-Most peloids dissolved away, matrix is well cemented microspar with some LMC replacement of skeletal allochems.

Porosity

-Pelmoldic porosity at ~25%, very high effective porosity.

Comments

-Marine limestone, shallow shoal, protected setting.



Thin-Section Description

Sample: **T-3BS1 - GW1 - 10.0**

Rock Type: Peloid and skeletal lime packstone.

Grain Types

Carbonate:

10% lime mud: matrix of microspar and lime mud;

35% skeletal: bivalve fragments, gastropod fragments, benthic foraminifers, ostracods, some unidentified skeletal grains;

40% non-skeletal: peloids dominant, most 150-400 mm, possible coated grains;

Accessory Grains:

2-3% quartz sand: most ~200 mm diameter, subangular, low sphericity;

Comments: none

Diagenesis

-Some peloids dissolved away, most skeletal grains leached and replaced with LMC spar.

-LMC spar cement.

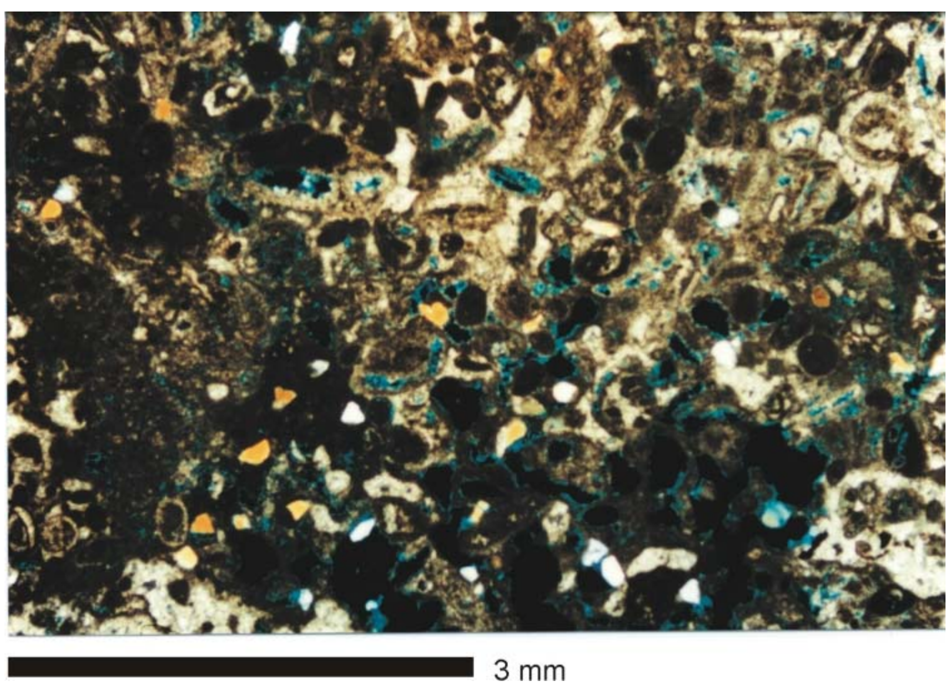
Porosity

-Pelmoldic and interparticle porosity at ~15%, high effective porosity.

Comments

-Marine limestone, shallow shoal with mixed peloids and skeletal grains.

-Some areas of possible root penetration and micrite root structures.



Thin-Section Description

Sample: **T-3BS1 - GW1 - 11.0**

Rock Type: Wackestone, lime mud matrix with bivalve, ostracod, and gastropod allochems.

Grain Types

Carbonate:

75-80% lime mud: massive, matrix;

10-15% skeletal: bivalve fragments, gastropod fragments, benthic foraminifers, ostracods, some unidentified skeletal grains;

Accessory Grains:1-2% quartz sand: most 100-200 mm diameter, angular, low sphericity;

Comments: none

Diagenesis

-Some skeletal grains leached and replaced with LMC spar.

-LMC spar cement.

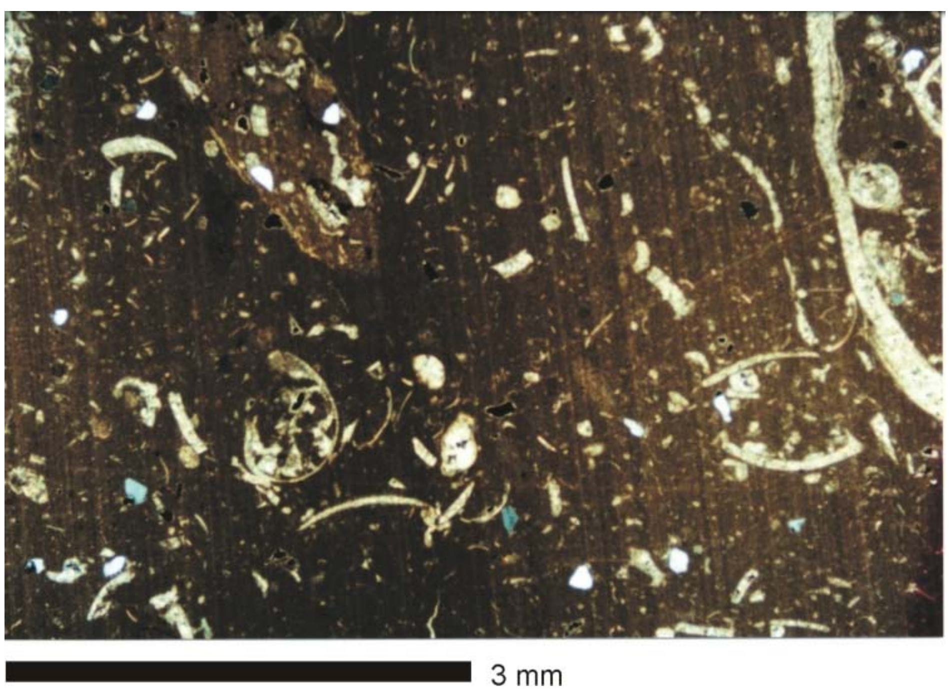
Porosity

-Moldic porosity at ~5-10%, low effective porosity.

Comments

-Possible calcrete/root structure, laminated and concentric micrite structures.

-Marine limestone, mud-rich setting, relatively low energy.



Thin-Section Description

Sample: **T-3BS1 - GW1 - 16.0**

Rock Type: Benthic foraminifer floatstone, lime mud and skeletal matrix (wackestone).

Grain Types

Carbonate:

40% lime mud: massive, matrix;

35-40% skeletal: benthic foraminifers (miliolid, Archaias), bivalve fragments, some unidentified skeletal grains;

1-2% nonskeletal: few peloids present;

Accessory Grains:

1-2% quartz sand: most 100-200 mm diameter, angular, low sphericity;

Comments: none

Diagenesis

-Some skeletal grains leached and replaced with LMC spar.

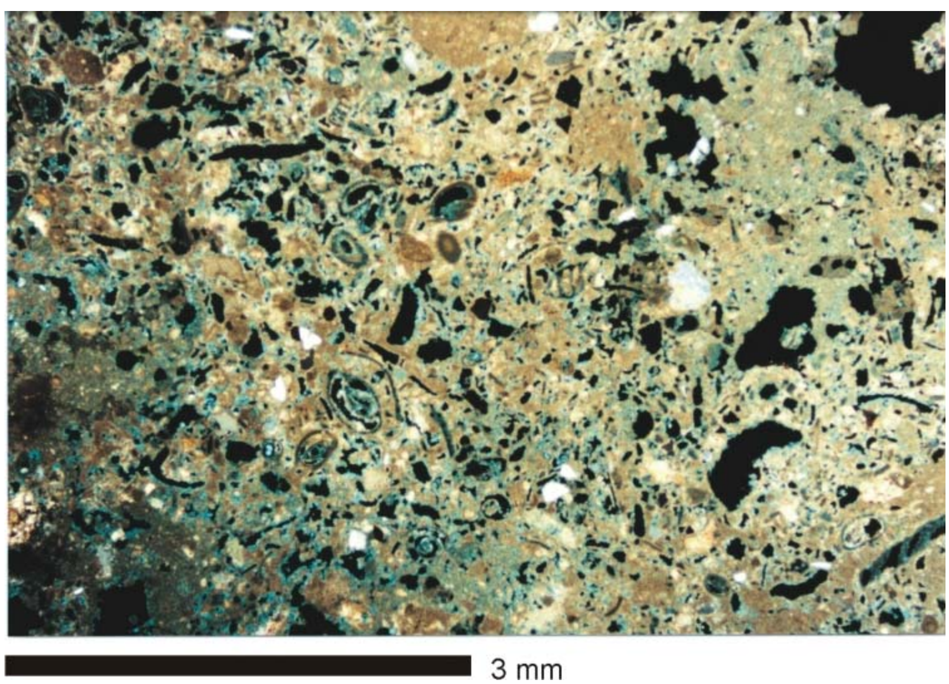
-LMC spar cement.

Porosity

-Moldic porosity at ~15-20%, moderate-high effective porosity.

Comments

-Marine limestone, lagoon setting, relatively low energy, rich in benthic foraminifers and lime mud.



Thin-Section Description

Sample: **T-3BS1 - GW1 - 17.5**

Rock Type: Lime mudstone with some benthic foraminifer allochems.

Grain Types

Carbonate:

80-90% lime mud: possible peloid origin, some evidence visible;

<15% skeletal: benthic foraminifers (miliolid, Spirolina, Archaias), thin-walled bivalve fragments, possible ostracods;

Accessory Grains:

trace% quartz sand: most <100 mm diameter, angular, low sphericity;

Comments: none

Diagenesis

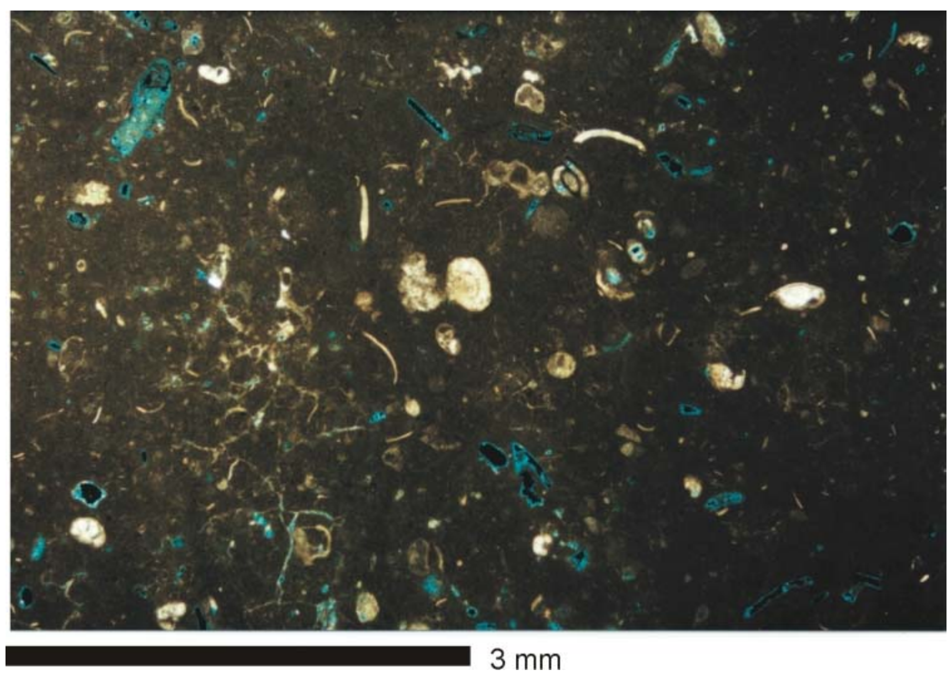
-Most skeletal grains leached and replaced with LMC spar, few remain partially open.

Porosity

-Moldic porosity at 5%, low effective porosity.

Comments

-Marine limestone, lagoon setting, relatively low energy, rich in lime mud that was perhaps partially deposited as peloidal sand.



Thin-Section Description

Sample: **T-3BS1 - GW1 - 25.0**

Rock Type: Gastropod floatstone with a matrix of lime mud and fine skeletal debris (wackestone).

Grain Types

Carbonate:

80% lime mud: matrix, massive, some evidence of an original peloid origin;

10-12% skeletal: large (>2 mm) gastropod fragments, bivalve fragments, benthic foraminifers;

Accessory Grains:

1-2% quartz sand: most ~100 mm diameter, angular, low sphericity;

Comments: none

Diagenesis

-Most skeletal grains leached and replaced with LMC spar.

-Few open molds associated with large dissolved gastropod shells and other skeletal allochems.

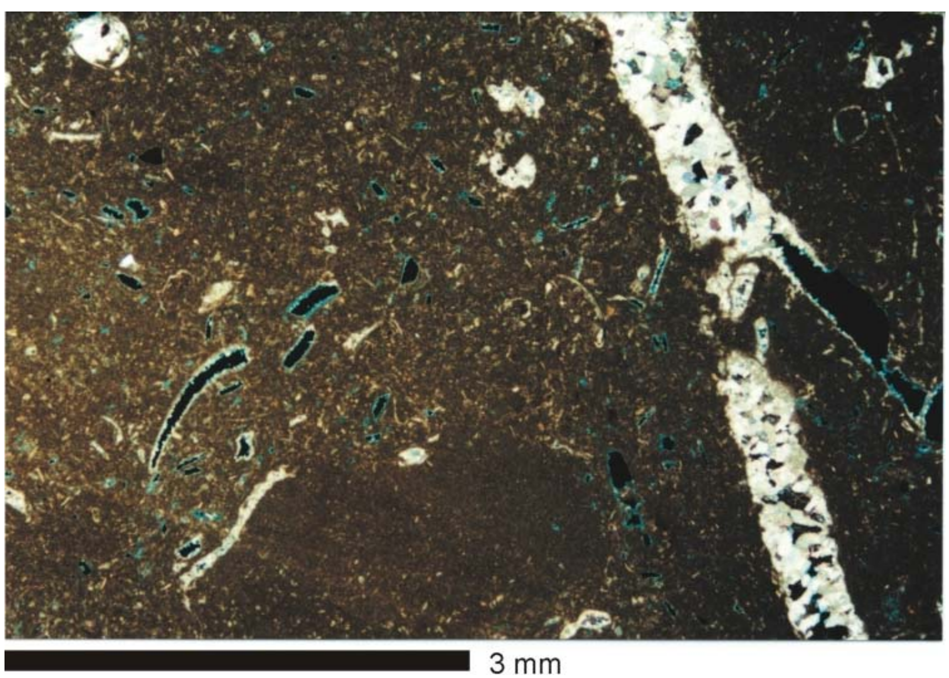
Porosity

-Moldic porosity at 8-10%, related to dissolution of skeletal allochems, low effective porosity.

Comments

-Marine limestone, lagoon setting, relatively low energy.

-Mixed skeletal allochems, lime mud, and probably some peloidal sand.



Thin-Section Description

Sample: **T-3BS1 - GW1 - 32.0**

Rock Type: Benthic foraminifera, bivalve packstone with matrix of lime mud and very fine quartz sand.

Grain Types

Carbonate:

60-70% skeletal: benthic foraminifers (Archaias, miliolid, possible Spirolina), bivalve fragments, gastropod fragments;

15-20% lime mud: mixture of mud- and silt-sized skeletal debris;

Accessory Grains:

5% quartz sand: most ~200 mm diameter, v. angular to angular, low sphericity;

Comments: Benthic foraminifers dominant skeletal type.

Diagenesis

-Most skeletal grains leached and replaced with LMC spar.

-Few open molds associated with dissolved skeletal allochems.

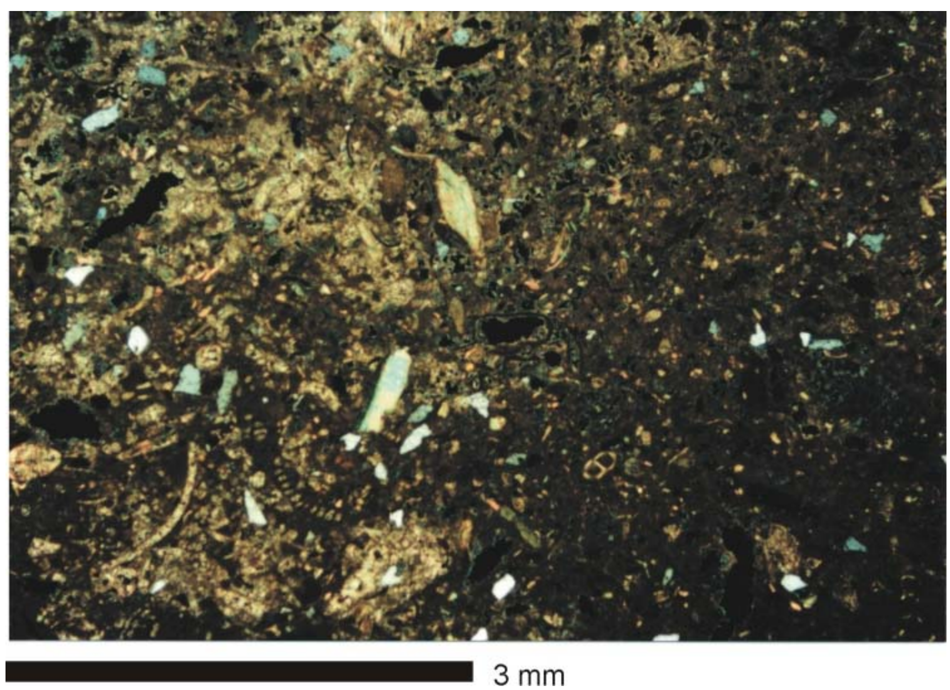
-LMC spar cement.

Porosity

-Moldic porosity at 15%, from dissolution of skeletal allochems, moderately high effective porosity.

Comments

-Marine limestone, shell hash, beach or storm concentration, lagoon setting.



Thin-Section Description

Sample: **T-3BS1 - GW2 - 8.0**

Rock Type: Bivalve, bryozoan floatstone in peloid packstone matrix.

Grain Types

Carbonate:
35% skeletal: bivalve fragments, bryozoan fragments, echinoderms;
30% non-skeletal: peloids abundant, most 200-400 mm;
15% lime mud: matrix of microspar and lime mud;
Accessory Grains:
5% quartz sand: most ~200 mm diameter, subangular to subrounded, moderate sphericity;
Comments: none

Diagenesis

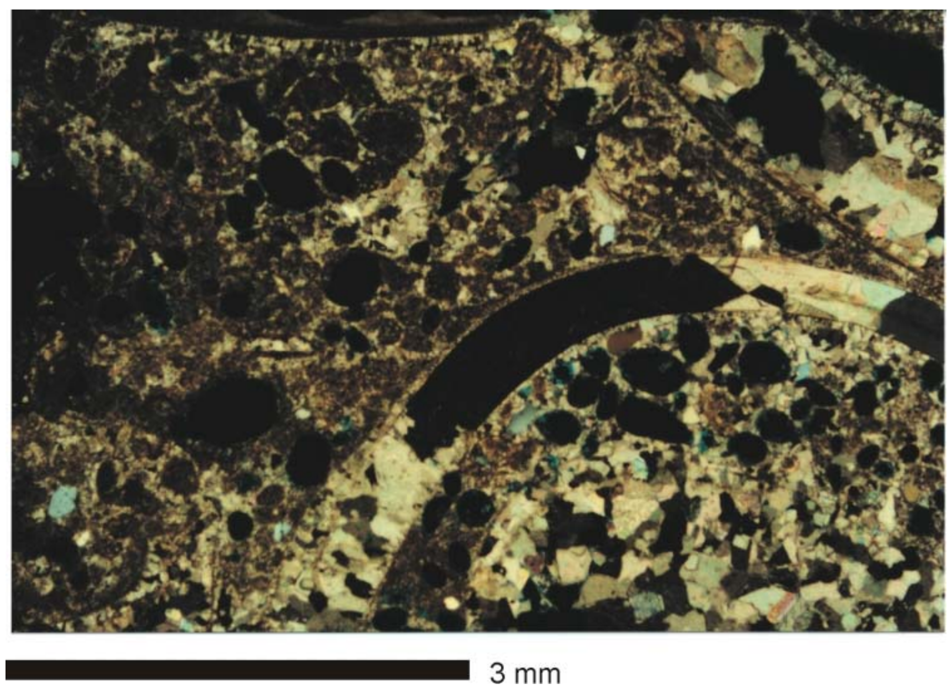
-LMC spar replacement of large skeletal fragments, LMC cement abundant.

Porosity

-Pelmoldic porosity and skeletal moldic porosity at 15%, high effective porosity.

Comments

-Marine limestone, semi-protected, shallow shoal.



Thin-Section Description

Sample: **T-3BS1 - GW2 - 9.0**

Rock Type: Bryozoan, benthic foraminifera, bivalve floatstone in packstone matrix of lime mud and quartz sand.

Grain Types

Carbonate:

30% skeletal:, chelistrome bryozoan fragments, benthic foraminifera (Archaias, possible Sorites), bivalve fragments echinoderm plates;

20% non-skeletal: peloids abundant, most 200-400 mm, possible root molds;

15% lime mud: matrix of microspar and lime mud;

Accessory Grains:

15% quartz sand: most 100-300 mm diameter, subangular, low sphericity;

Comments: none

Diagenesis

-LMC spar replacement of large skeletal fragments.

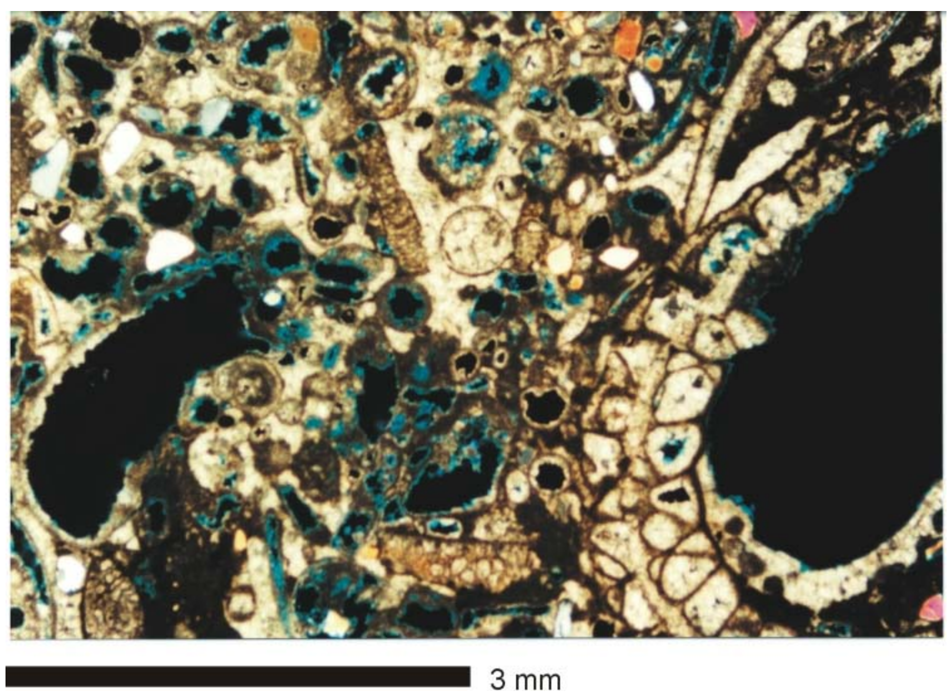
-LMC cement abundant.

Porosity

-Pelmoldic porosity and skeletal moldic porosity at ~20%, very high effective porosity.

Comments

-Marine limestone, semi-protected, shallow shoal.



Thin-Section Description

Sample: **T-3BS1 - GW2 - 11.0**

Rock Type: Bivalve, bryozoan, benthic foraminifera floatstone in packstone matrix of lime mud, quartz sand, and calcrete micrite.

Grain Types

Carbonate:

30% skeletal:, bivalve fragments, chelistrome bryozoan fragments, benthic foraminifers (Archaias);

25% non-skeletal: peloids 200-400 mm, possible root molds w/ laminated calcrete;

15% lime mud: matrix of lime mud;

Accessory Grains:

10% quartz sand: most 100-300 mm diameter, subangular, low sphericity;

<1% intraclasts of calcite cemented quartz sand;

Comments: none

Diagenesis

-LMC spar replacement of skeletal fragments.

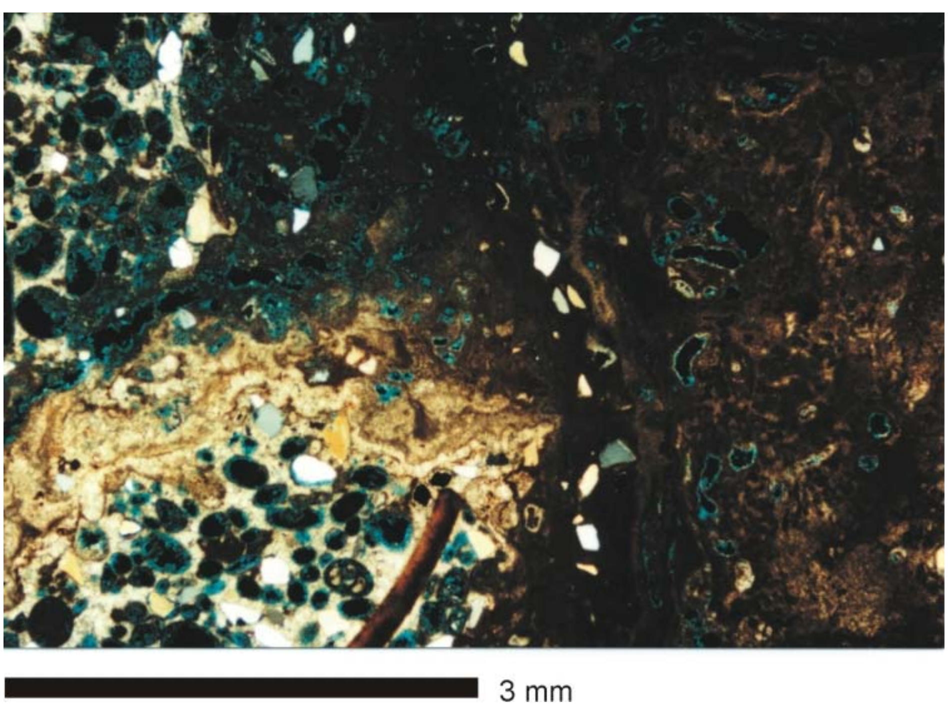
-LMC cement abundant.

Porosity

-Pelmoldic porosity and skeletal moldic porosity at ~20%, very high effective porosity.

Comments

-Marine limestone, semi-protected, shallow shoal. Contains calcrete related to subaerial exposure.



Thin-Section Description

Sample: **T-3BS1 - GW2 - 13.5**

Rock Type: Mudstone-wackestone, lime mud matrix with skeletal allochems, evidence of peloidal sand.

Grain Types

Carbonate:

75% lime mud: matrix of lime mud, massive, some evidence of peloids in thin-section;

10% skeletal: ostracod tests, very fine unidentified skeletal fragments, bivalve fragments, benthic foraminifers, spines/spicules;

Accessory Grains:

~1% quartz sand: most 150-200 mm diameter, subangular, low sphericity;

Comments: none

Diagenesis

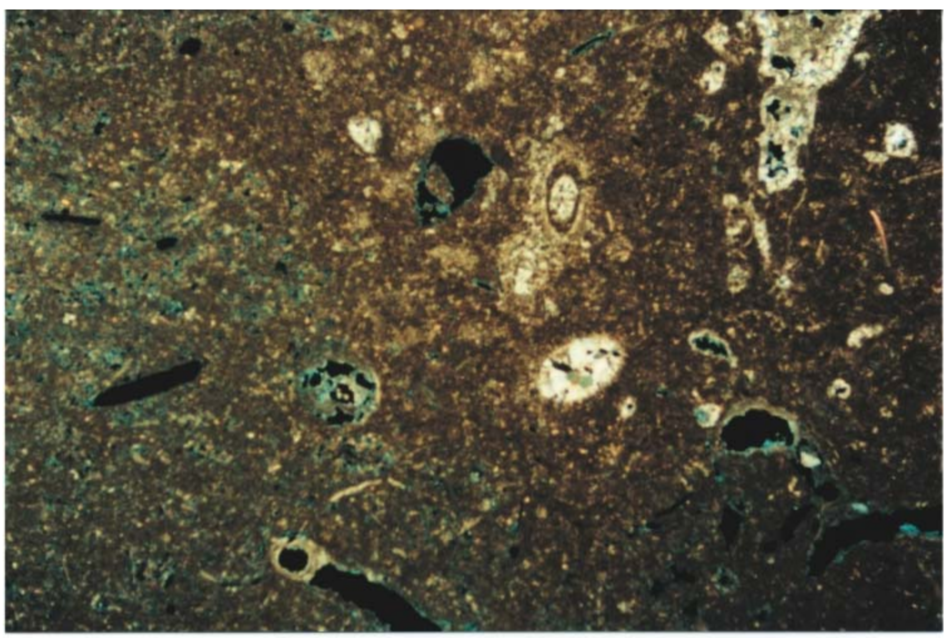
-Dissolution of skeletal grains, minor LMC infill of voids.

Porosity

-Moldic porosity and micro-porosity at ~15%, relatively low effective porosity.

Comments

-Marine limestone, semi-protected. Possible peloid and lime mud deposition.



3 mm

Thin-Section Description

Sample: **T-3BS1 - GW2 - 14.5**

Rock Type: Mudstone-wackestone, lime mud matrix with minor skeletal allochems and evidence of peloidal sand.

Grain Types

Carbonate:

75% lime mud: matrix of lime mud, some evidence of peloids in thin-section;

10% skeletal: ostracod tests, bivalve fragments, benthic foraminifers;

Accessory Grains:

trace% quartz sand: most 100 mm diameter, subangular, moderate sphericity;

Comments: Note possible root molds in mud matrix.

Diagenesis

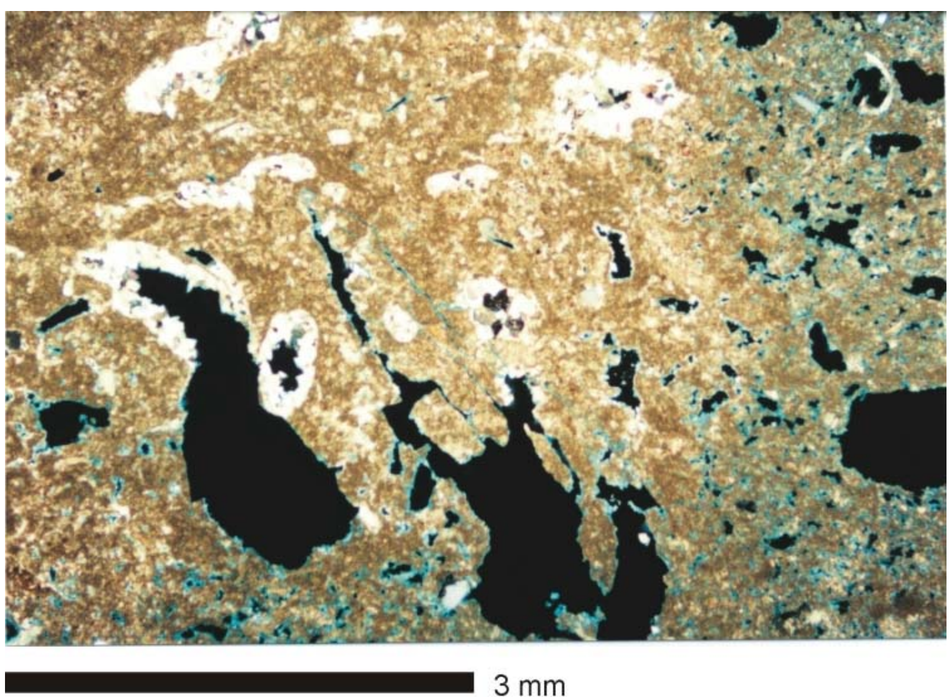
-Dissolution of skeletal grains, minor LMC infill of voids.

Porosity

-Moldic porosity and some interparticle porosity at ~15%, moderate effective porosity.

Comments

-Marine limestone, semi-protected setting. Mixed peloid and lime mud deposition.



Thin-Section Description

Sample: **T-3BS1 - GW2 - 19.0**

Rock Type: Wackestone, lime mud matrix with benthic foraminifers, bivalve and gastropod allochems.

Grain Types

Carbonate:

65% lime mud: matrix of lime mud, massive;

15% skeletal: benthic foraminifers, bivalve and gastropod fragments, ostracod tests, very fine unidentifiable skeletal debris;

Accessory Grains: none

Comments: none

Diagenesis

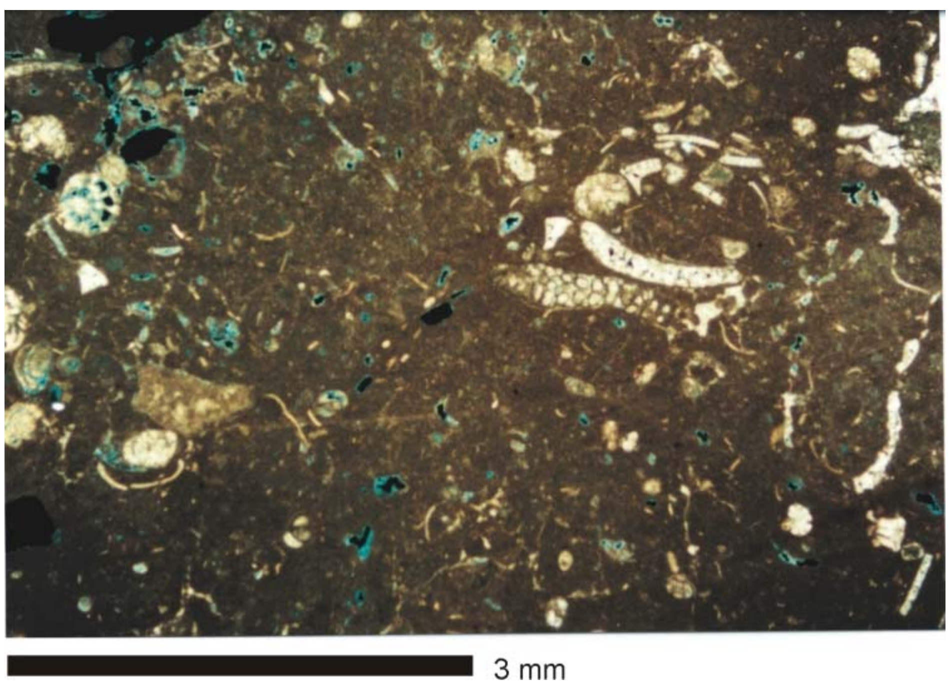
-Dissolution of skeletal grains, most infilled with LMC spar.

Porosity

-Moldic porosity and some micro-porosity at ~20%, moderate effective porosity.

Comments

-Marine limestone, protected setting. Mixed lime mud and minor skeletal grains.



Thin-Section Description

Sample: **T-3BS1 - GW2 - 28.0**

Rock Type: Bivalve floatstone with wackestone-packstone matrix of skeletal sand, quartz sand, and lime mud.

Grain Types

Carbonate:

65% skeletal: benthic foraminifers, (Archaias), bivalve and gastropod fragments, ostracod tests, very fine unidentifiable skeletal debris;

15% lime mud: matrix of lime mud, massive;

Accessory Grains:

5% quartz sand, most 100-150 mm, subangular, low sphericity;

Comments: none

Diagenesis

-Dissolution of skeletal grains, most benthic foraminifers and bivalves infilled with LMC spar.

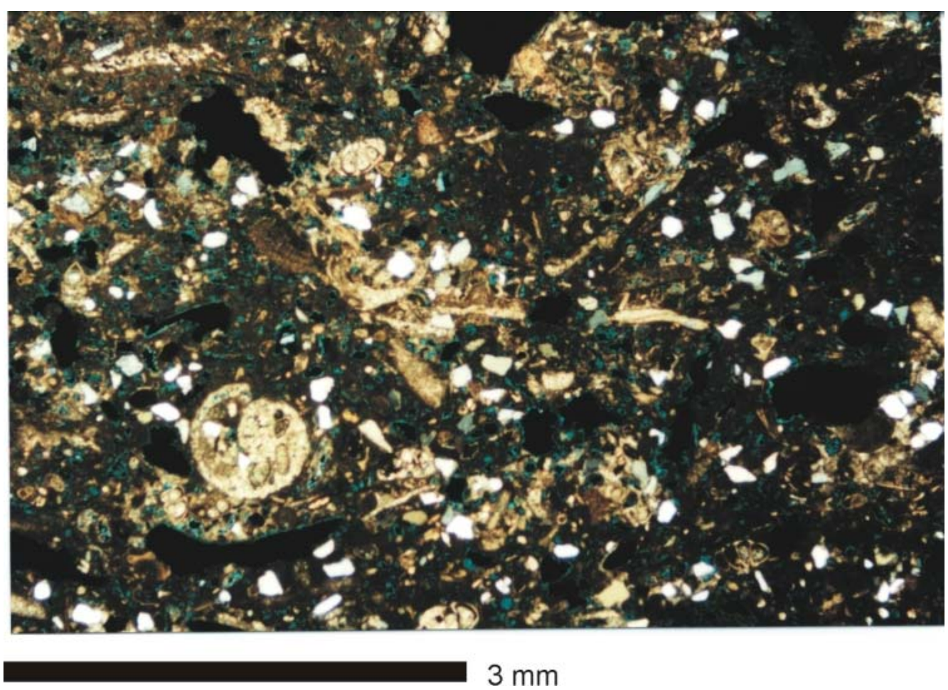
-LMC spar cement.

Porosity

-Moldic porosity at ~20%, moderate to high effective porosity.

Comments

-Marine skeletal limestone, open lagoon setting. Mixed skeletal grains with some lime mud.



Thin-Section Description

Sample: **T-3BS1 - GW3 - 6.5**

Rock Type: Peloid grainstone-packstone.

Grain Types

Carbonate:

65-70% non-skeletal: peloids abundant, most 200-400 mm;

20-25% lime mud: matrix of microspar and lime mud;

5% skeletal: bivalve fragments, bryozoan fragments, echinoderms;

Accessory Grains:

5% quartz sand: most 200-300 mm diameter, subangular to subrounded, moderate sphericity;

Comments: Possible skeletal intraclasts.

Diagenesis

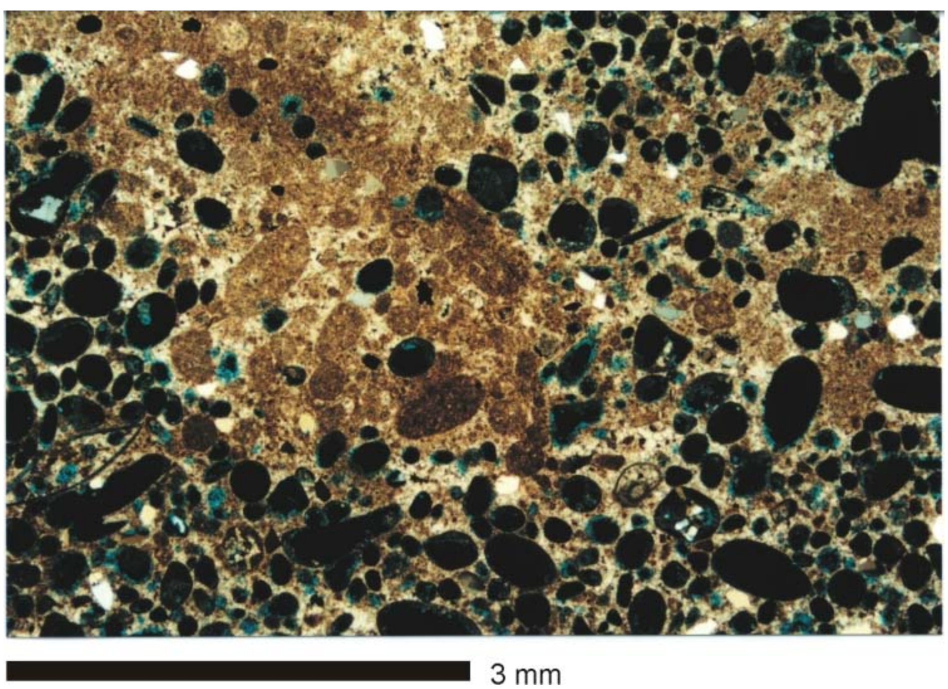
-LMC spar cementation of peloids, and widespread leaching of peloids.

Porosity

-Pelmoldic porosity is ~45-50% of total thin section area (not normalized), high effective porosity.

Comments

-Marine limestone, semi-protected, shallow peloid sand shoal.



Thin-Section Description

Sample: **T-3BS1 - GW3 - 8.0**

Rock Type: Micritic limestone (wackestone) with root molds, calcrete.

Grain Types

Carbonate:

75% non-skeletal/lime mud: some peloids and areas of clotted peloids, root molds matrix of micrite as laminated calcrete and lime mud;

5% skeletal: bivalve fragments, bryozoan fragments, echinoderms, possible red algae, benthic foraminifers (Spirolina?);

Accessory Grains:

5% quartz sand: most 150-250 mm diameter, subrounded, moderate sphericity, variable distribution, high percent in laminated calcrete on upper part of thin-section;

Comments: none

Diagenesis

-LMC spar replacement of skeletal grains and cementation.

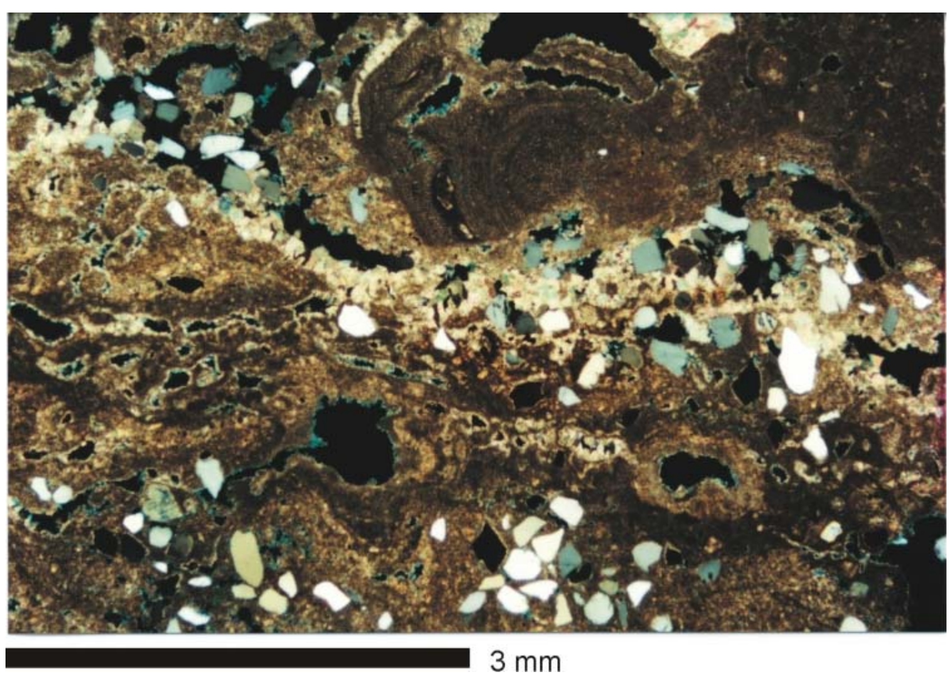
-Root mold penetration and micrite precipitation.

Porosity

-Root mold porosity and interparticle porosity at15%, moderate effective porosity.

Comments

-Marine limestone, altered to calcrete with root penetration due to subaerial exposure processes.



Thin-Section Description

Sample: **T-3BS1 - GW3 - 12.5**

Rock Type: Lime wackestone with benthic foraminifera, skeletal allochems.

Grain Types

Carbonate:

65-70% skeletal: benthic foraminifers (miliolid, possible Archaias), echinoderm spines, bivalve fragments;

30% lime mud matrix: massive, hint of peloids in matrix;

Accessory Grains:

2-3% quartz sand: most ~200 mm diameter, subrounded, moderate sphericity;

Comments: none

Diagenesis

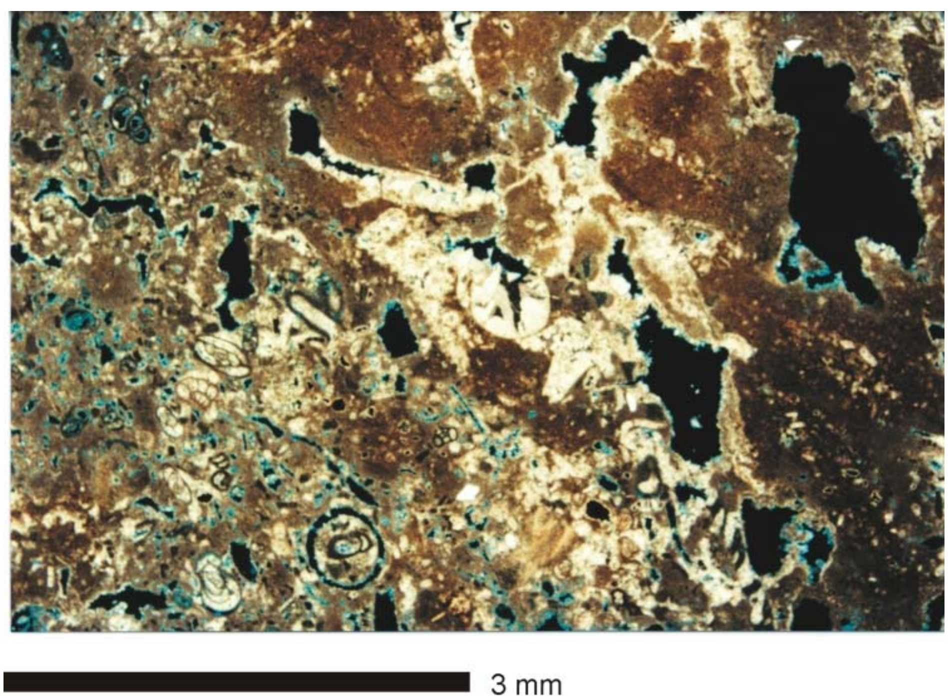
-LMC spar replacement of skeletal grains and cementation.

Porosity

-Moldic porosity and interparticle porosity at 15-20%, moderate-high effective porosity.

Comments

-Marine limestone, benthic foraminifera-rich lagoonal sands.



Thin-Section Description

Sample: **T-3BS1 - GW3 - 23.0**

Rock Type: Gastropod floatstone with matrix of lime mud and skeletal allochems (wackestone).

Grain Types

Carbonate:
60% lime mud: matrix, massive;
20% skeletal: >2 mm gastropod fragments, bivalves, benthic foraminifers;
Accessory Grains:
1-2% quartz sand: variable size from 100-400 mm diameter, subrounded, moderate-high sphericity;
Comments: none

Diagenesis

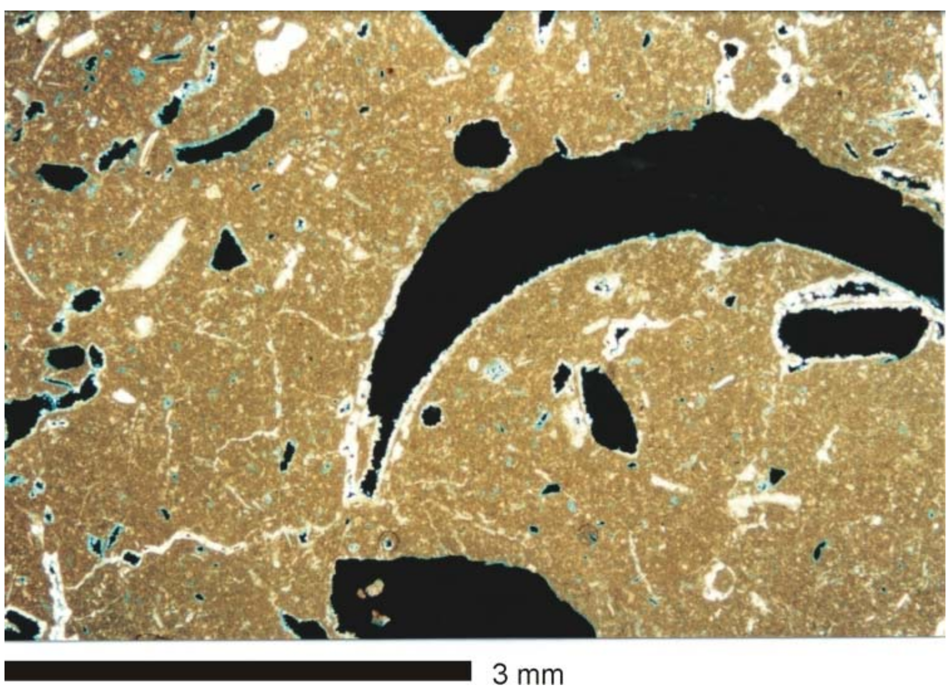
-Dissolution of large shell fragments yielding open molds.
-Smaller skeletal grains replaced with LMC spar.

Porosity

-Moldic porosity and some minor micro-porosity at ~18%, moderate-high effective porosity.

Comments

-Marine limestone, mud-rich, low-energy lagoon deposit.



Thin-Section Description

Sample: **T-3BS1 - GW3 - 24.0**

Rock Type: Benthic foraminifera packstone-wackestone with lime mud and quartz sand.

Grain Types

Carbonate:

50-60% skeletal: benthic foraminifers (Archaias, miliolid), bivalve fragments, gastropod fragments, some unidentified skeletal grains;

10-20% lime mud: matrix, massive;

Accessory Grains:

5-8% quartz sand: variable size from 150-300 mm diameter, subangular, low sphericity, variable distribution;

Comments: none

Diagenesis

-Dissolution of shell fragments, some open molds.

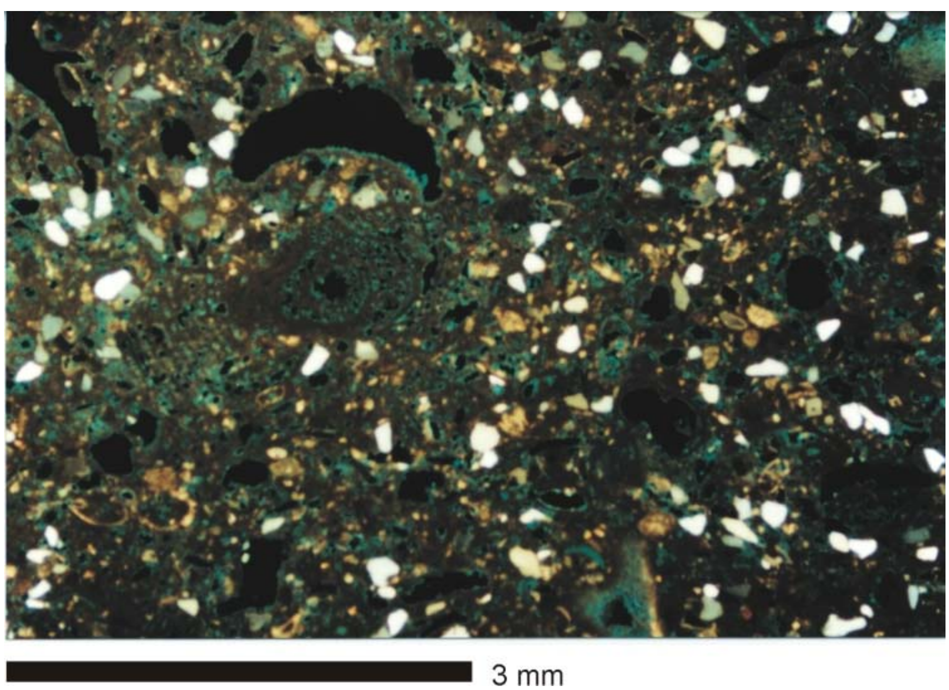
-Many skeletal grains replaced with LMC spar, LMC spar cement.

Porosity

-Moldic porosity and interparticle porosity with total at 25%, high effective porosity.

Comments

-Marine limestone, mixed skeletal sand, lime mud, quartz sand likely related to a moderate- to low-energy lagoon setting.



Thin-Section Description

Sample: **T-3BS1 - GW3 - 26.0**

Rock Type: Benthic foraminifera wackestone with matrix of lime mud, skeletal allochems, and quartz sand.

Grain Types

Carbonate:

35% lime mud: matrix, massive;

30% skeletal: benthic foraminifers (Archaias, Spirolina, miliolid), bivalve fragments, some small unidentified skeletal grains;

Accessory Grains:

10% quartz sand: most ~200 mm diameter, subangular, moderate sphericity;

Comments: none

Diagenesis

-Dissolution of shell fragments, some open molds.

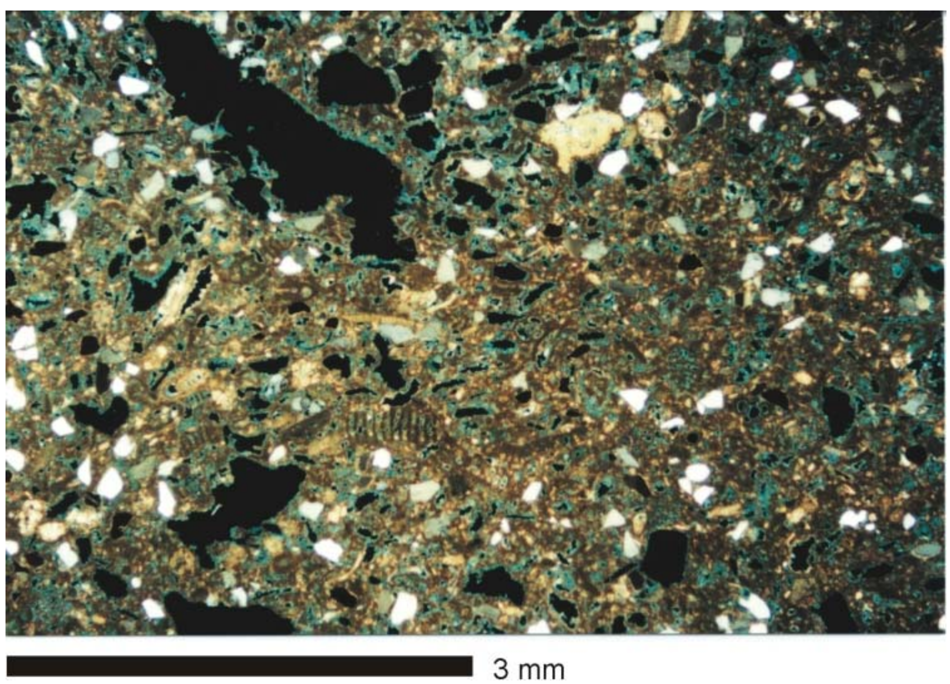
-Micrite/microspar cementation.

Porosity

-Moldic porosity and interparticle porosity at ~25%, high effective porosity.

Comments

-Marine limestone, low-energy lagoon setting.



Thin-Section Description

Sample: **T-3BS1 - GW4 - 13.0**

Rock Type: Benthic foraminifera and bivalve floatstone with matrix of peloids and skeletal allochems.

Grain Types

Carbonate:

20% non-skeletal: peloids 200-400 mm, possible root molds;

30% lime mud: mixed matrix of lime mud and micrite possibly related to root structures;

20% skeletal: bivalve fragments, benthic foraminifers (Sorites, miliolid, Archaias);

Accessory Grains:

5% quartz sand: most 100-300 mm diameter, subangular, moderate sphericity

trace% carbonate intraclasts;

Comments: Iron-staining (light orange) in some areas of thin section.

Diagenesis

-Many open voids outside of possible intraclasts due to peloid dissolution.

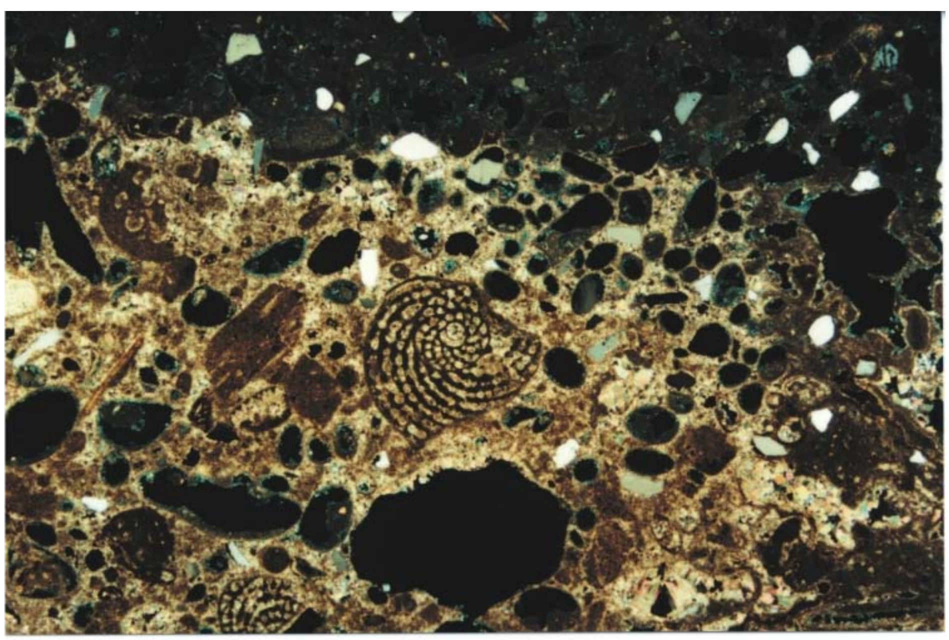
-Intraclasts cemented with LMC spar.

Porosity

-Moldic porosity at 25% of total thin section area, high effective porosity.

Comments

-Marine limestone modified by subaerial exposure, intraclasts, roots.



3 mm

Thin-Section Description

Sample: **T-3BS1 - GW4 - 15.0**

Rock Type: Lime wackestone, matrix lime mud with quartz sand and skeletal allochems.

Grain Types

Carbonate:

70% lime mud: matrix of lime mud, some evidence of peloids, possible lime mud intraclasts;

5% skeletal: bryozoan fragments, bivalve fragments, echinoderm plate;

Accessory Grains:

15% quartz sand: most 100-300 mm diameter, subangular, moderate sphericity;

Comments: Possible root mold structures.

Diagenesis

-Few open pores (molds?).

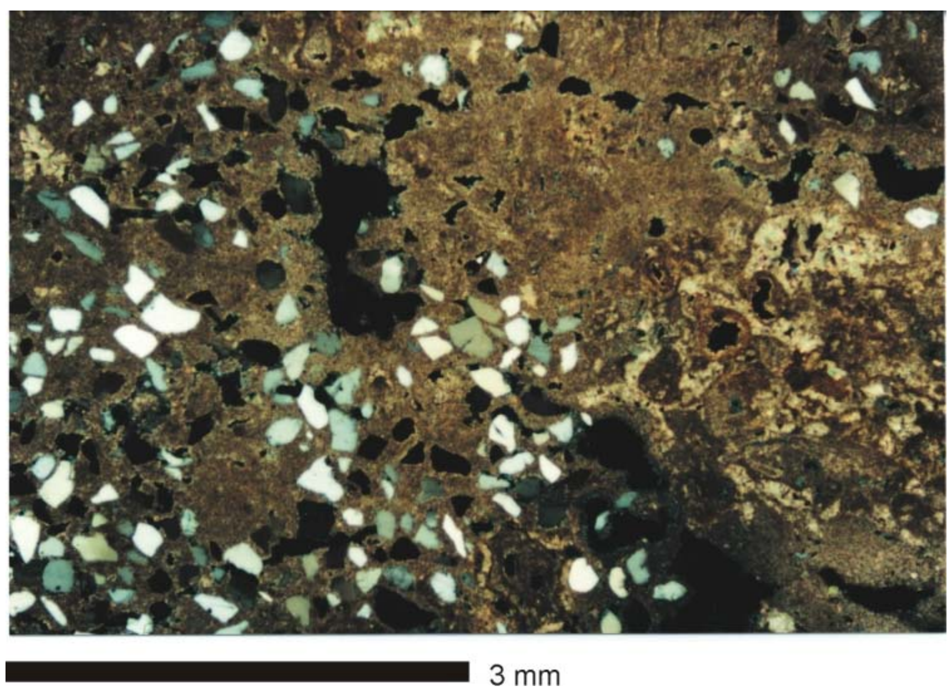
-Micrite and LMC spar cement.

Porosity

-Moldic porosity at 10% of total thin section due to dissolution of skeletal grains and open root molds, moderate-high effective porosity.

Comments

-Marine limestone, restricted lagoon setting.



Thin-Section Description

Sample: **T-3BS1 - GW4 - 19.5**

Rock Type: Benthic foraminifera wackestone, matrix of lime mud and skeletal allochems.

Grain Types

Carbonate:

40% skeletal: benthic foraminifers (miliolid, Archaias), bryozoan fragments, bivalve fragments, echinoderm plate;

30% lime mud: matrix of lime mud, some evidence of peloids, possible lime mud intraclasts;

10% nonskeletal: peloids;

Accessory Grains:

5% quartz sand: most 100-300 mm diameter, subangular, moderate sphericity;

Comments: none

Diagenesis

-Few open pores (molds?).

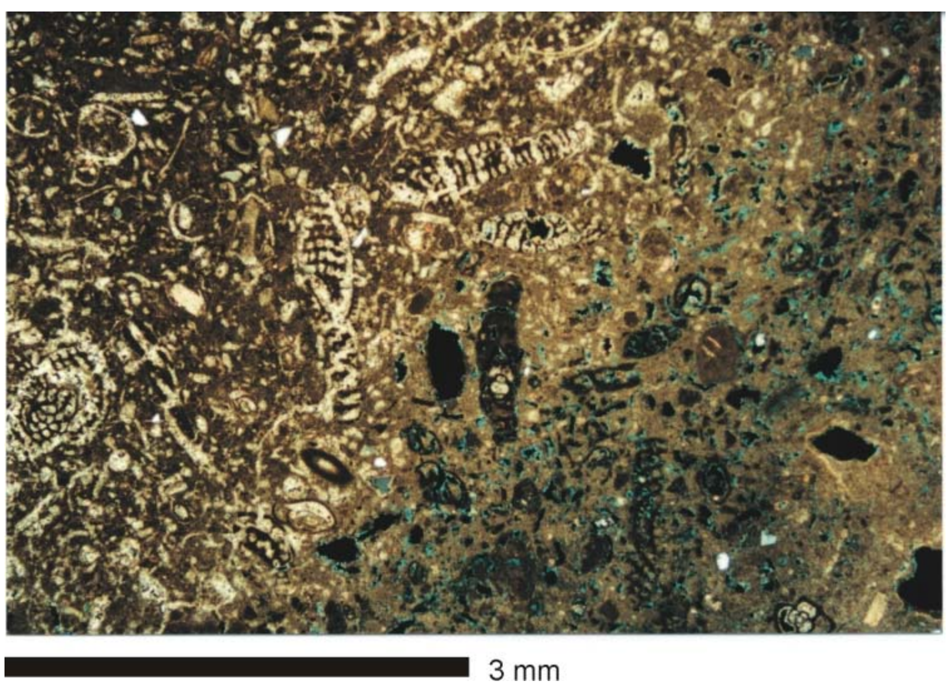
-Micrite and LMC spar cement.

Porosity

-Moldic porosity and interparticle porosity at 15% of total thin section due to dissolution of skeletal grains and open molds, moderate effective porosity.

Comments

-Marine limestone, skeletal sand and mud, open lagoon setting.



Thin-Section Description

Sample: **T-3BS1 - GW4 - 23.0**

Rock Type: Peloidal wackestone, matrix of lime mud and skeletal allochems.

Grain Types

Carbonate:

35% skeletal: benthic foraminifers (miliolid, Archaias, Spirolina), bivalve fragments, ostracods, echinoderm plate, gastropod fragments;

25% lime mud: matrix of lime mud, some evidence of peloids, possible lime mud intraclasts;

20% nonskeletal: peloids;

Accessory Grains:

1% quartz sand: most 100-200 mm diameter, subangular, moderate sphericity;

Comments: none

Diagenesis

-Few open molds, small skeletal grains replaced by LMC spar.

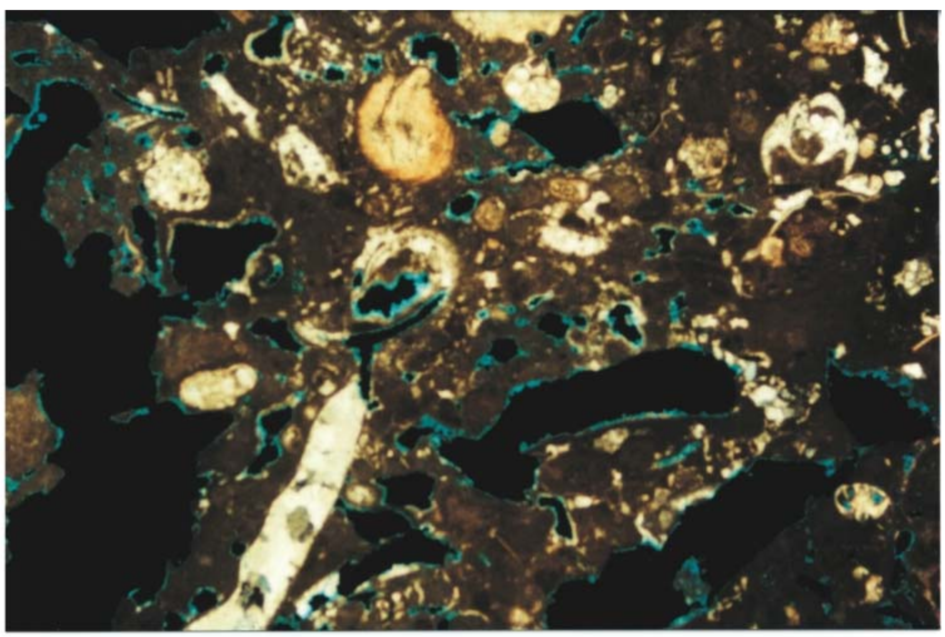
-Micrite and LMC spar cement.

Porosity

-Moldic porosity and interparticle porosity at ~20% of total thin section due to dissolution of skeletal grains and open molds, some root molds remain open, moderate effective porosity.

Comments

-Marine limestone, skeletal sand and mud, open lagoon setting.



3 mm

Thin-Section Description

Sample: **T-3BS1 - GW4 - 26.0**

Rock Type: Lime packstone-wackestone, matrix of skeletal (benthic foraminifera and bivalve) allochems and lime mud.

Grain Types

Carbonate:
40% skeletal: bivalve fragments, benthic foraminifers (miliolids, Sorites, Archaias);
20% nonskeletal: peloids;
20% lime mud: matrix of lime mud, some evidence of peloids;
Accessory Grains:
1-2% quartz sand: most 150-200 mm diameter, subrounded, moderate sphericity;
Comments: none

Diagenesis

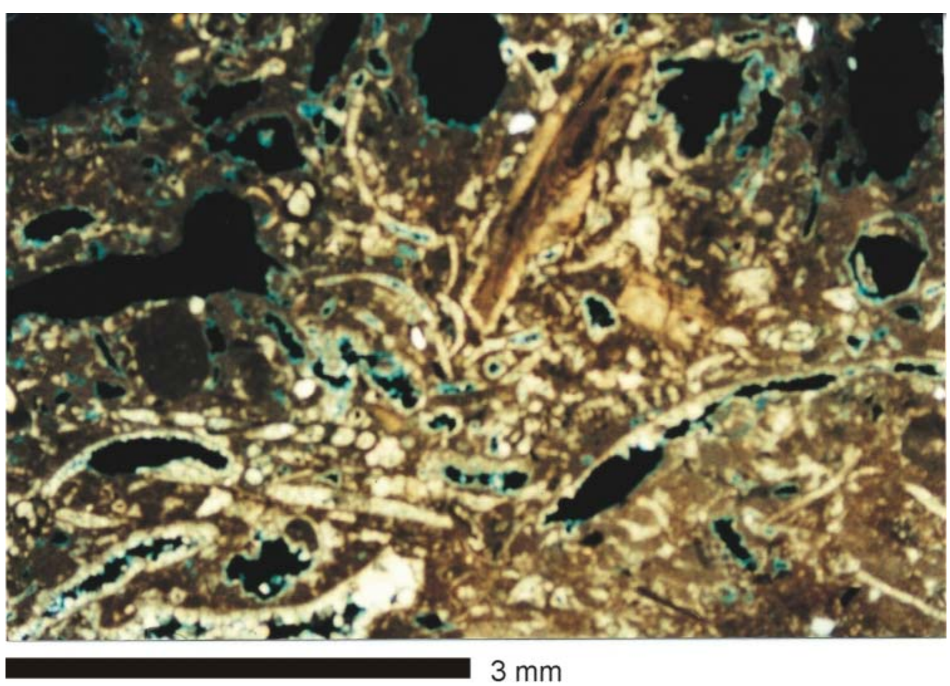
-Many open and filled molds, small skeletal grains replaced by LMC spar.
-LMC spar cement.

Porosity

-Moldic porosity and interparticle porosity at ~20% of total thin section from dissolution of skeletal grains, high effective porosity.

Comments

-Marine limestone, skeletal sand, peloids, and mud, open lagoon setting.



Thin-Section Description

Sample: **T-3BS1 - GW4 - 31.0**

Rock Type: Lime mudstone containing some bivalve fragments.

Grain Types

Carbonate:
90% lime mud: matrix of lime mud, massive;
5% skeletal: thin-walled bivalve fragments, ostracods;
Accessory Grains:
trace% quartz sand: ~100 mm diameter, angular, low sphericity;
Comments: none

Diagenesis

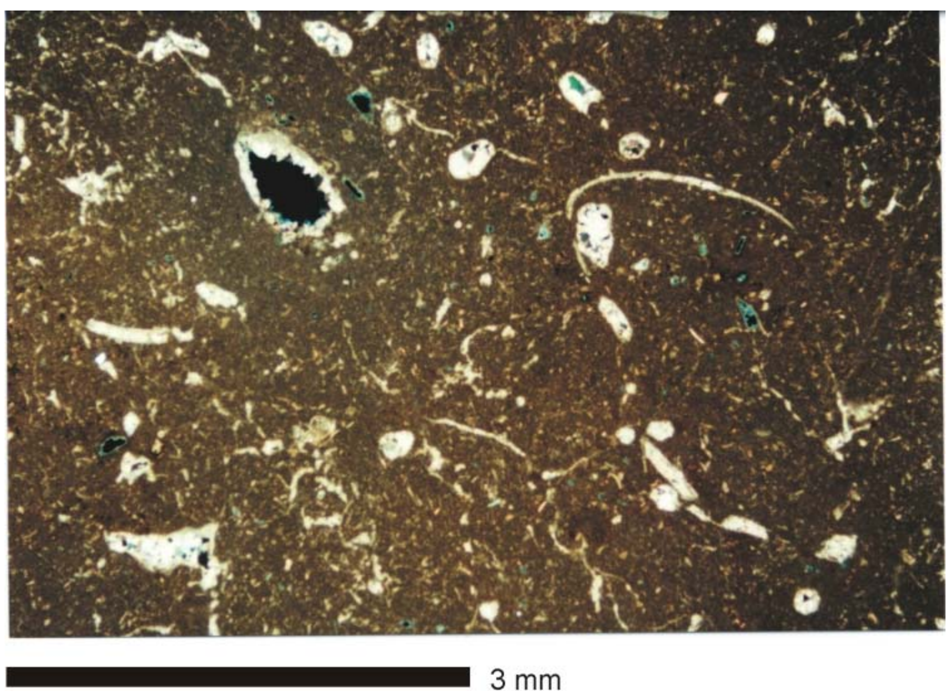
-Small microfractures filled with LMC spar, few skeletal grains replaced with LMC spar.

Porosity

-Some moldic porosity and interparticle porosity at 5% of total thin section, molds from dissolution of skeletal grains, low effective porosity.

Comments

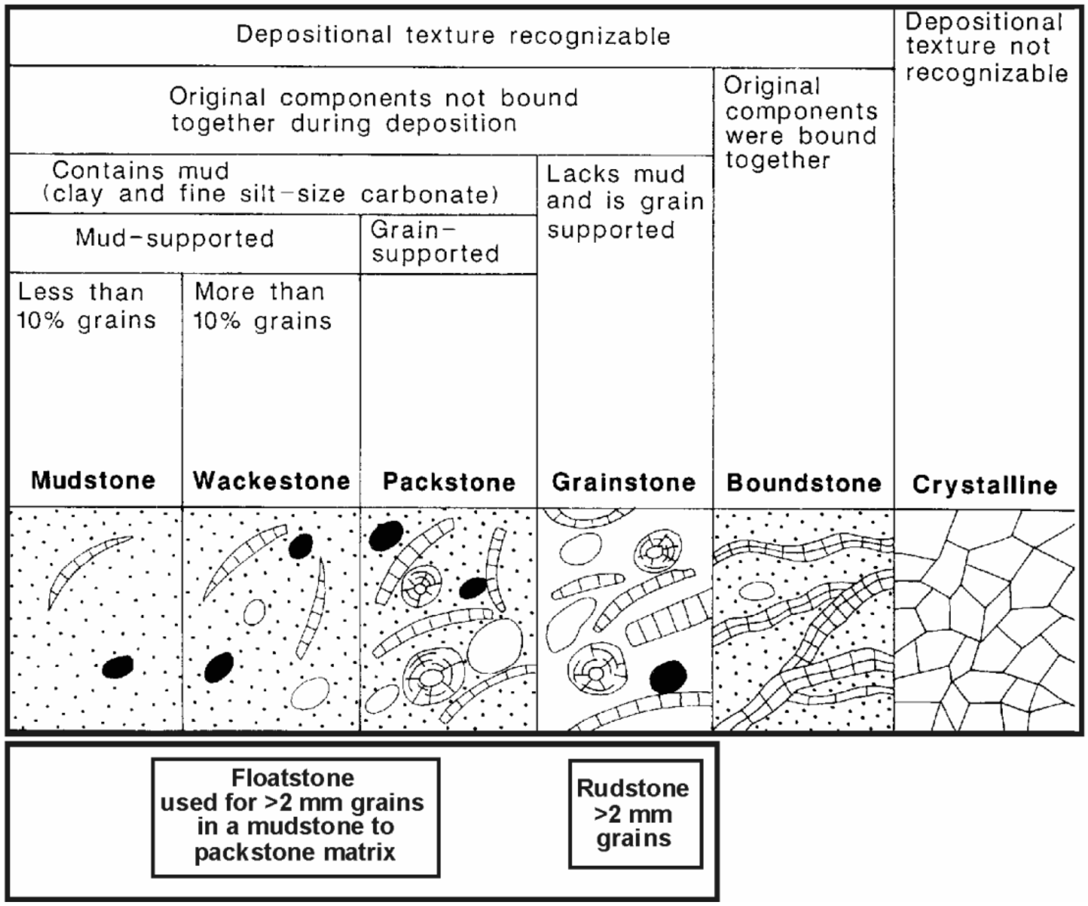
-Marine lime mud, mudbank in a protected lagoon setting.

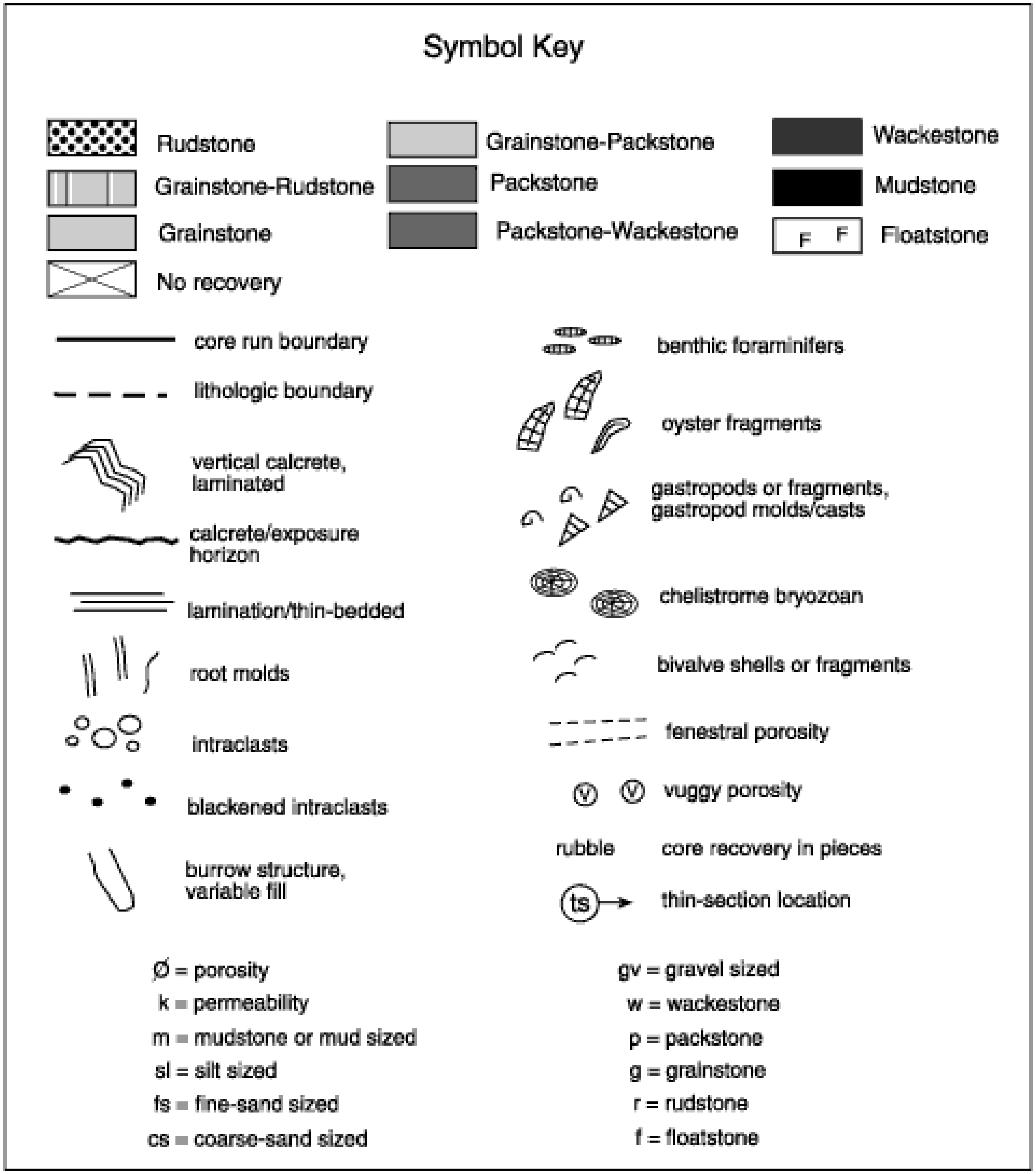


APPENDIX II

Core Descriptions and Graphic Summaries

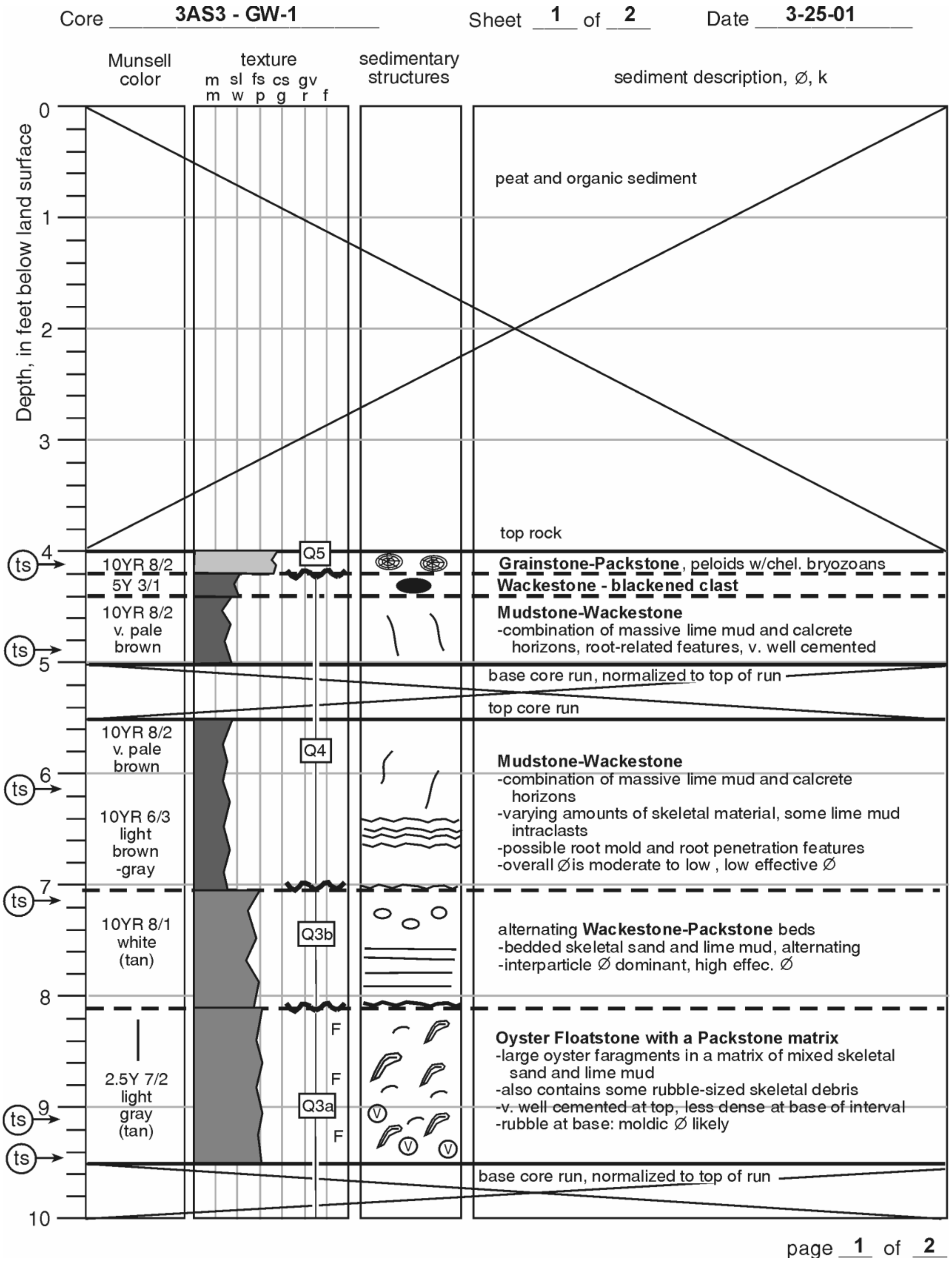
Modified Dunham Classification

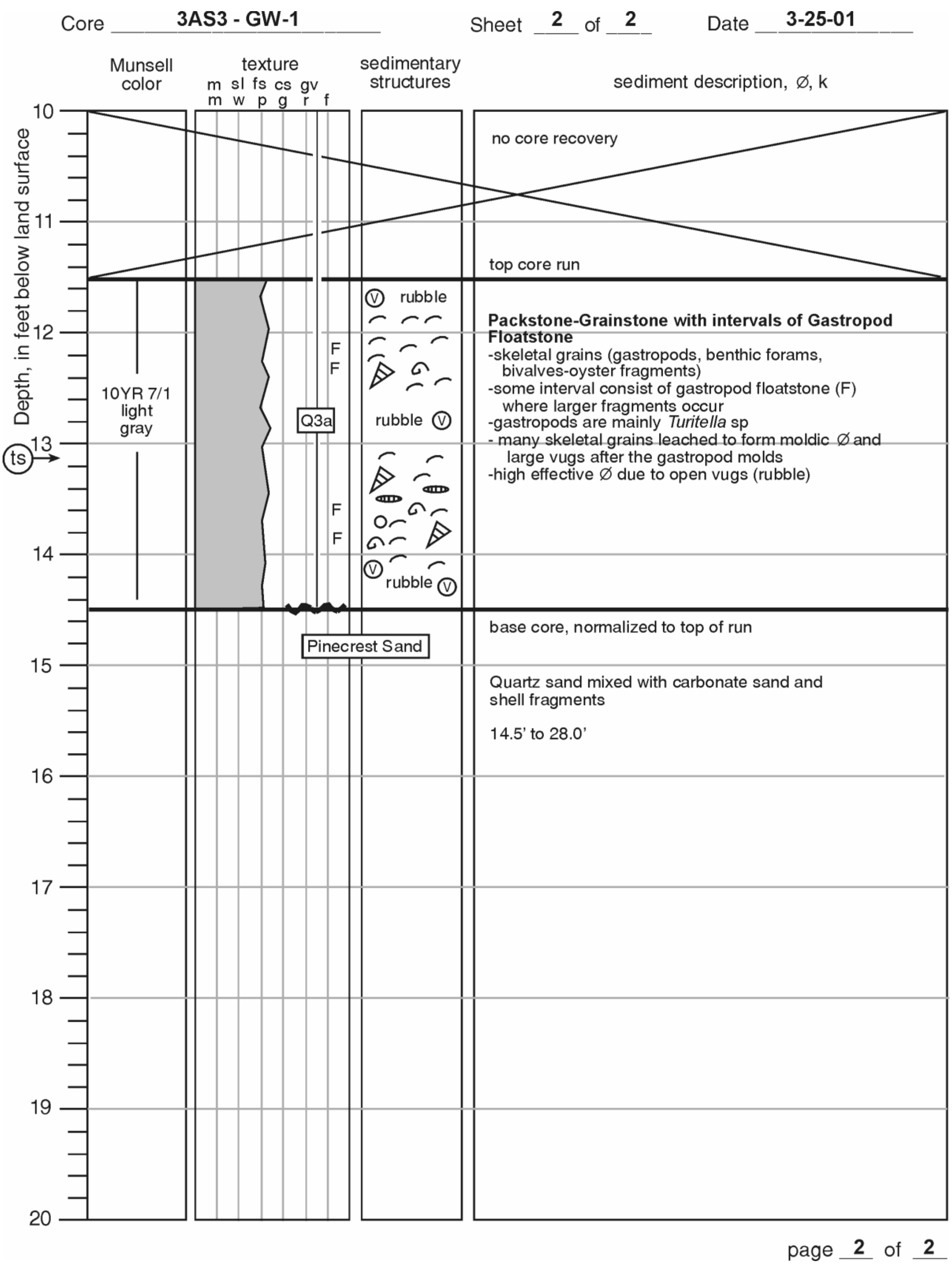



Symbol Key
Rudstone
Grainstone-Rudstone
Grainstone
No recovery
Grainstone-Packstone
Packstone
Packstone-Wackestone
Wackestone
Mudstone
F F
Floatstone
core run boundary
lithologic boundary
vertical calcrete, laminated
calcrete/exposure horizon
lamination/thin-bedded
root molds
intraclasts
blackened intraclasts
burrow structure, variable fill
benthic foraminifers
oyster fragments
gastropods or fragments, gastropod molds/casts
chelistrome bryozoan
bivalve shells or fragments
fenestral porosity
V V
vuggy porosity
rubble
core recovery in pieces
ts
thin-section location
Ø = porosity
k = permeability
m = mudstone or mud sized
sl = silt sized
fs = fine-sand sized
cs = coarse-sand sized
gv = gravel sized
w = wackestone
p = packstone
g = grainstone
r = rudstone
f = floatstone

Core 3AS3-GW-1

0-4.0'	Peat and Organic Sediment (not described).
4.00-4.17'	Lime Packstone with peloids and encrusting bryozoan fragments. Moderately well cemented, orange-stained. 10YR 8/2 very pale brown.
4.17-4.33'	Lime Wackestone (Blackened intraclast), lime-mud rich intraclast that has likely been blackened by subaerial exposure processes. 5Y 3/1 very dark gray.
4.33-5.00'	Lime Mudstone-Wackestone. Lime mud with only minor skeletal allochems and possible vertical root penetration features (cement filled). Skeletal allochems unidentifiable. Unit is very well cemented with <5% porosity, very low effective porosity.
5.00-5.50'	No recovery, core normalized to top of run. Base of core run at 5.5'.
5.50-7.00'	Lime Mudstone-Wackestone, massive, lime-mud rich texture with variable amount of unidentified skeletal allochems (0-10%). Interval contains a laminated calcrete from 6.5-6.7'. A soil infilled vertical shaft occurs from about 6.0-6.5'. Possible root molds occur in the upper part of the interval. Minor amount of moldic porosity and likely microporosity (<5%), low effective porosity. 10YR 8/2 very pale brown to 10YR 6/2 light brown gray, and 10YR 6/3 pale brown for calcrete interval.
7.00-8.17'	Lime Wackestone to Packstone, mixture of skeletal sand and lime mud with some possible mud intraclasts. Skeletal allochems are likely bivalve fragments, although identification is uncertain due to fine grain size. Lower part of interval is laminated to thin-bedded. Moderately well cemented. Porosity is mainly interparticle at ~15-20% (higher in packstone textures). 10YR 6/2 light brown gray to 10YR 8/1 white (light tan).
8.17'	Sharp contact, likely subaerial exposure or hardground
8.17-9.50'	Lime Packstone to Oyster Floatstone, large oyster fragments, bivalves, and benthic foraminifers skeletal allochems mixed with minor amounts (10-15%) of lime mud and possible quartz sand (5-10%). Unit is very well cemented and dense at the top, less well cemented at base. Porosity is likely vuggy, moldic, and interparticle (some parts of core are rubble). High effective porosity below upper surface. 10YR 6/2 light brow-gray, slightly lighter at base.
9.50-11.5'	No recovery, core normalized to top of run. Base of core run at 11.5'.
11.50-14.50'	Mixed intervals of Packstone-Grainstone and Gastropod Floatstone. Matrix of skeletal sand and some lime mud containing oyster fragments, other bivalves, and high-spired gastropod (*Turitella* spp.) molds/casts. Porosity is mainly moldic after leaching of the gastropods shells, matrix is friable and likely vuggy in places (core recovery was rubble). Likely high effective porosity. 10YR 7/1 light gray (light tan-gray).
14.50-28.0'	Quartz sand mixed with carbonate sand and shell fragments (not described).

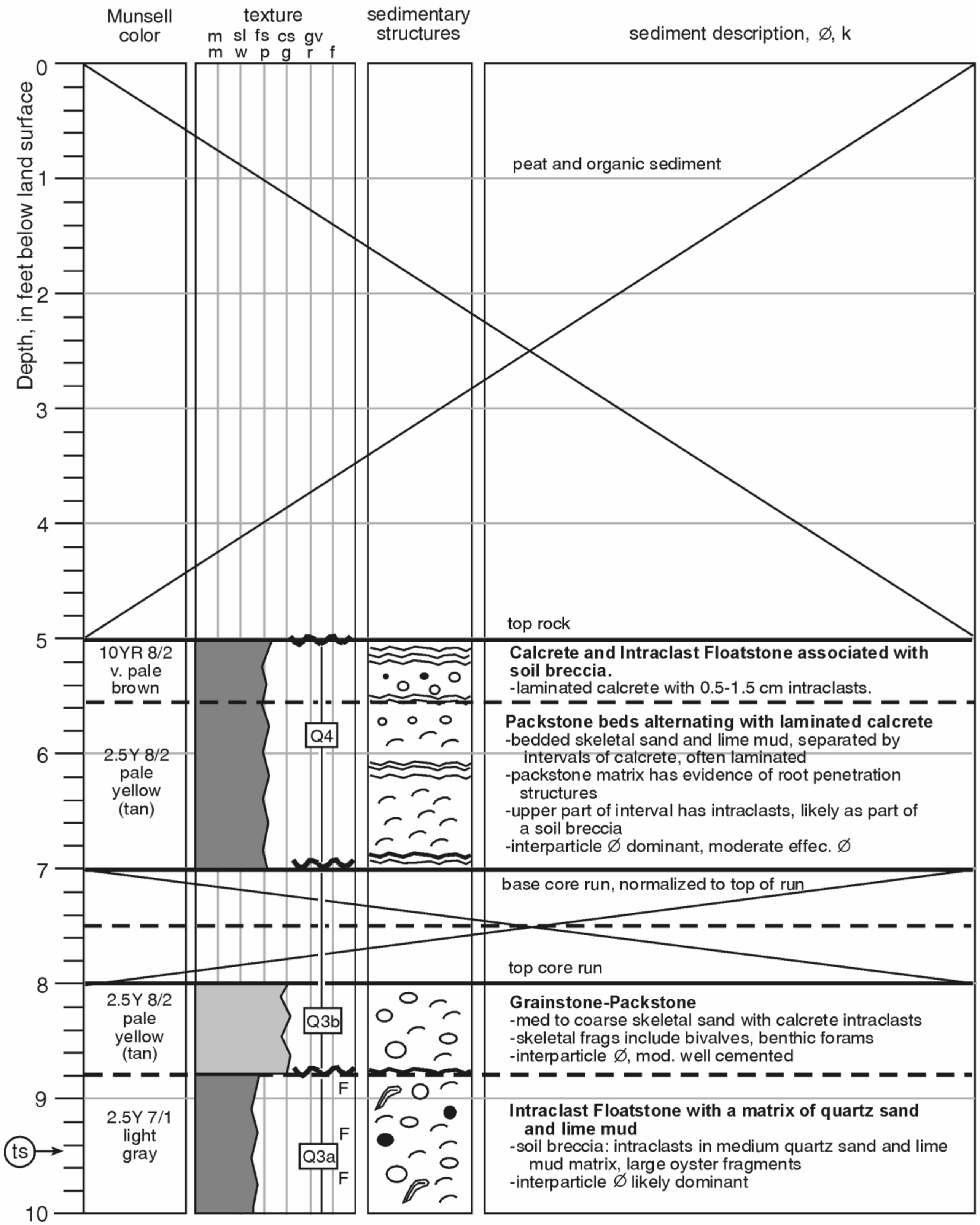

Core 3AS3 - GW-1
Sheet 1 of 2
Date 3-25-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
0
1
2
3
4
5
6
7
8
9
10
peat and organic sediment
top rock
ts
10YR 8/2
Q5
Grainstone-Packstone, peloids w/chel. bryozoans
5Y 3/1
Wackestone - blackened clast
10YR 8/2
v. pale
brown
Mudstone-Wackestone
-combination of massive lime mud and calcrete horizons, root-related features, v. well cemented
base core run, normalized to top of run
top core run
10YR 8/2
v. pale
brown
Q4
Mudstone-Wackestone
-combination of massive lime mud and calcrete horizons
-varying amounts of skeletal material, some lime mud intraclasts
-possible root mold and root penetration features
-overall Øis moderate to low , low effective Ø
10YR 6/3
light
brown
-gray
10YR 8/1
white
(tan)
Q3b
alternating Wackestone-Packstone beds
-bedded skeletal sand and lime mud, alternating
-interparticle Ø dominant, high effec. Ø
2.5Y 7/2
light
gray
(tan)
F
Q3a
V
Oyster Floatstone with a Packstone matrix
-large oyster faragments in a matrix of mixed skeletal sand and lime mud
-also contains some rubble-sized skeletal debris
-v. well cemented at top, less dense at base of interval
-rubble at base: moldic Ø likely
base core run, normalized to top of run
page 1 of 2


Core 3AS3 - GW-1
Sheet 2 of 2
Date 3-25-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
10
11
12
13
14
15
16
17
18
19
20
ts
no core recovery
top core run
10YR 7/1 light gray
Q3a
F
F
F
F
rubble
rubble
rubble
Packstone-Grainstone with intervals of Gastropod Floatstone
-skeletal grains (gastropods, benthic forams, bivalves-oyster fragments)
-some interval consist of gastropod floatstone (F) where larger fragments occur
-gastropods are mainly Turitella sp
- many skeletal grains leached to form moldic Ø and large vugs after the gastropod molds
-high effective Ø due to open vugs (rubble)
base core, normalized to top of run
Pinecrest Sand
Quartz sand mixed with carbonate sand and shell fragments
14.5' to 28.0'
page 2 of 2

Core 3AS3-GW-2

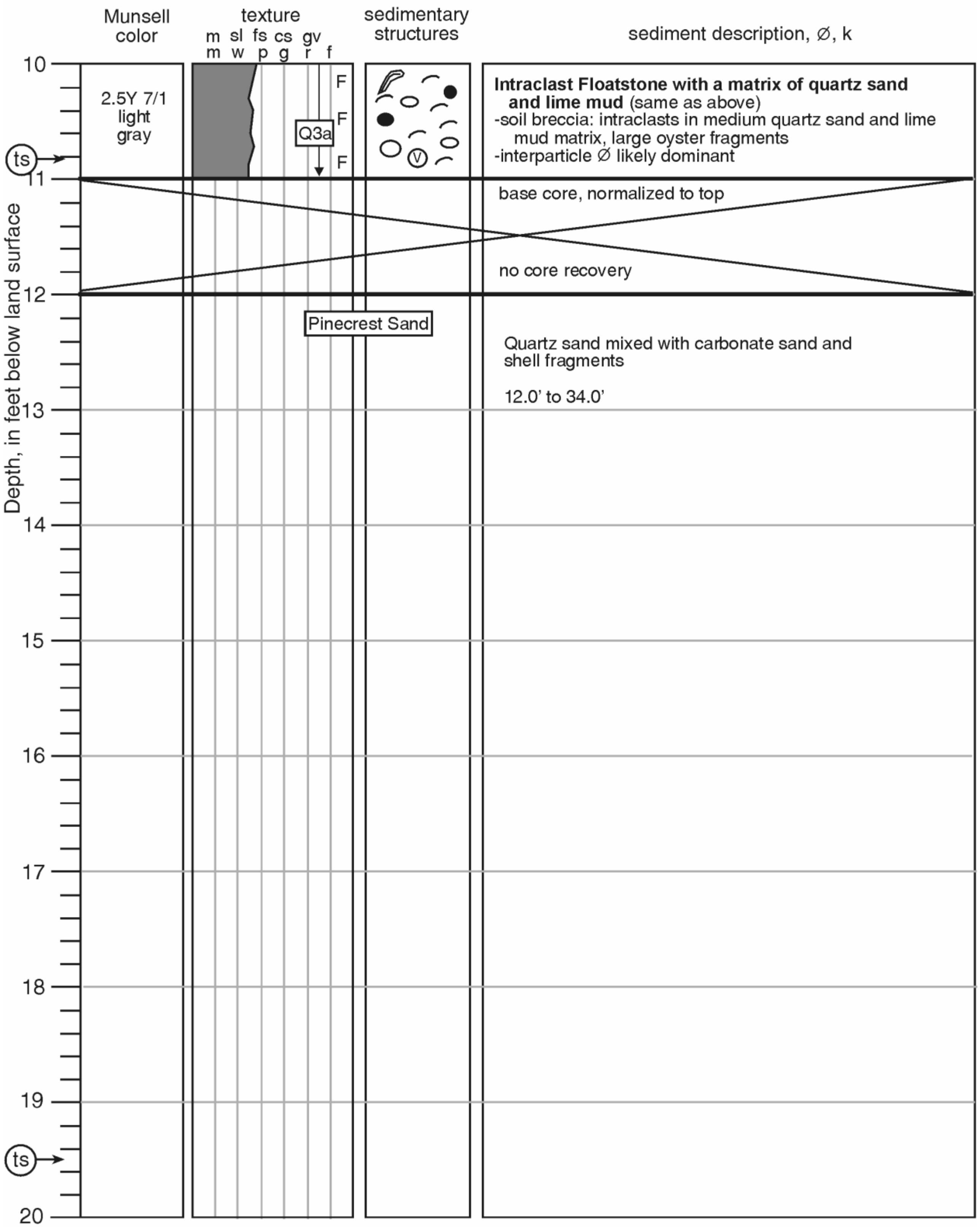
0-5.00'	Peat and Organic Sediment (not described).
5.00-5.50'	Calcrete and Intraclast Floatstone, laminated calcrete with soil breccia related to subaerial exposure processes. Well cemented. Interparticle and microporosity(?) at <10%, low effective porosity 10YR 8/2 very pale brown.
5.50-7.00'	Lime Packstone with intervals of laminated calcrete. Packstone intervals are skeletal sand with minor amount of lime mud. Skeletal allochems are mainly bivalve fragments, but contain possible root-altered fabric. Laminated calcrete at ~6.2' and 6.8'. Porosity is ~15% in the skeletal packstone intervals. Overall, moderate effective porosity. 2.5Y 8/2 pale yellow (light tan).
7.00-8.00'	No recovery, core normalized to top of run. Base of core run at 8.0'.
8.00-8.80'	Grainstone, medium- to coarse-skeletal sand with calcrete intraclasts (from underlying unit?). Skeletal allochems include bivalves and benthic foraminifers. Moderate-well cemented. Porosity is interparticle at ~15-20%. Moderate to high effective porosity. 2.5Y 8/2 pale yellow.
8.80'	Sharp contact, erosional, likely related to subaerial exposure.
8.80-11.00'	Intraclast Floatstone (soil breccia), mixed quartz sand, lime mud, large (0.5-1.5 cm) intraclasts and large oyster fragments. Some of the intraclasts may be of quartz sandstone composition. Porosity is mostly interparticle (5-10%), effective porosity is moderate. 2.5Y 7/1 light gray.
11.00-12.00'	No recovery, core normalized to top of run. Base of core run at 12.0'.
12.00-34.0'	Quartz-sand mixed with carbonate sand and shell fragments (not described).

Core 3AS3 - GW-2 Sheet 1 of 2 Date 3-26-01



page 1 of 2

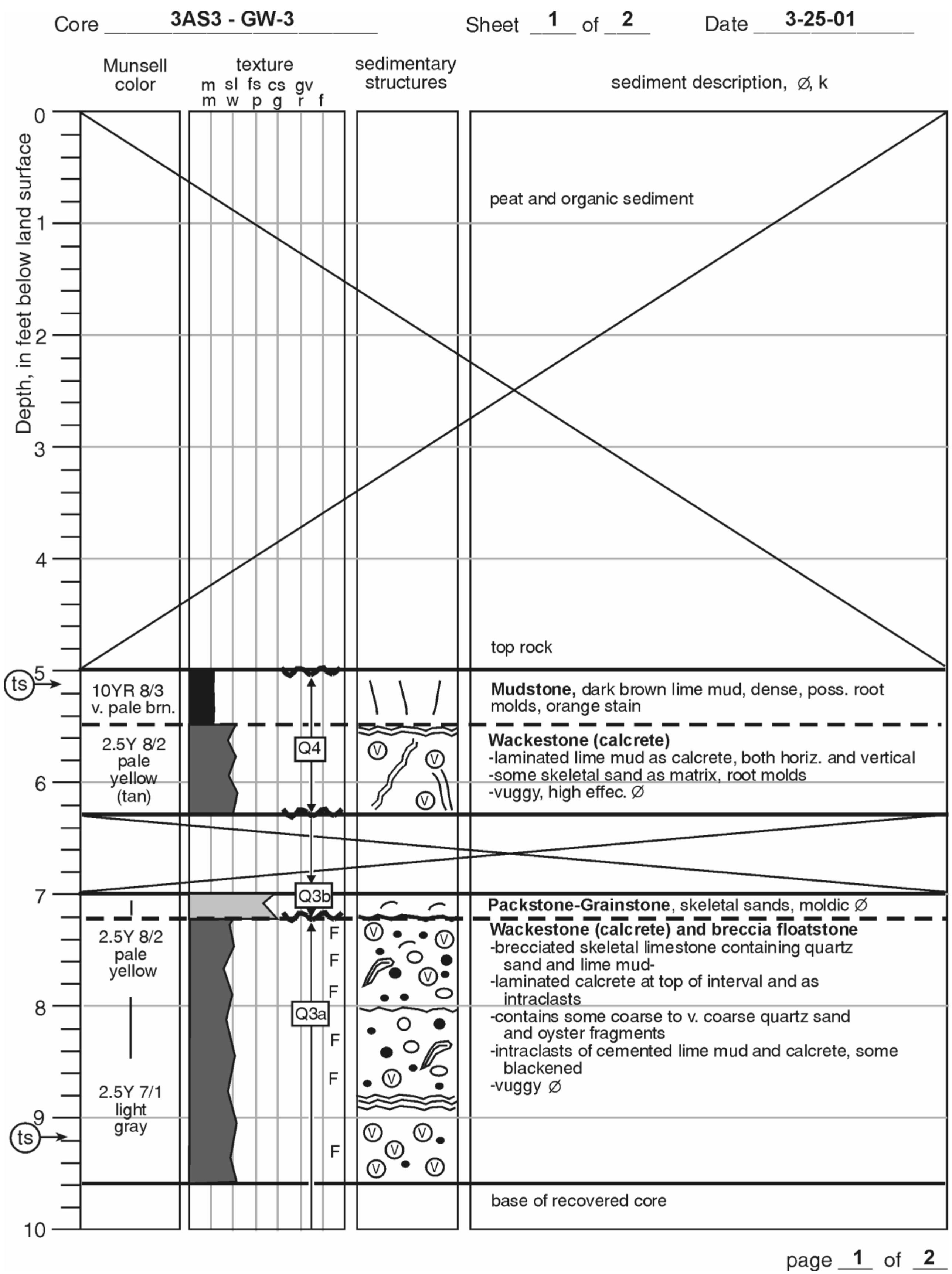
Core **3AS3 - GW-2** Sheet **2** of **2** Date **3-26-01**



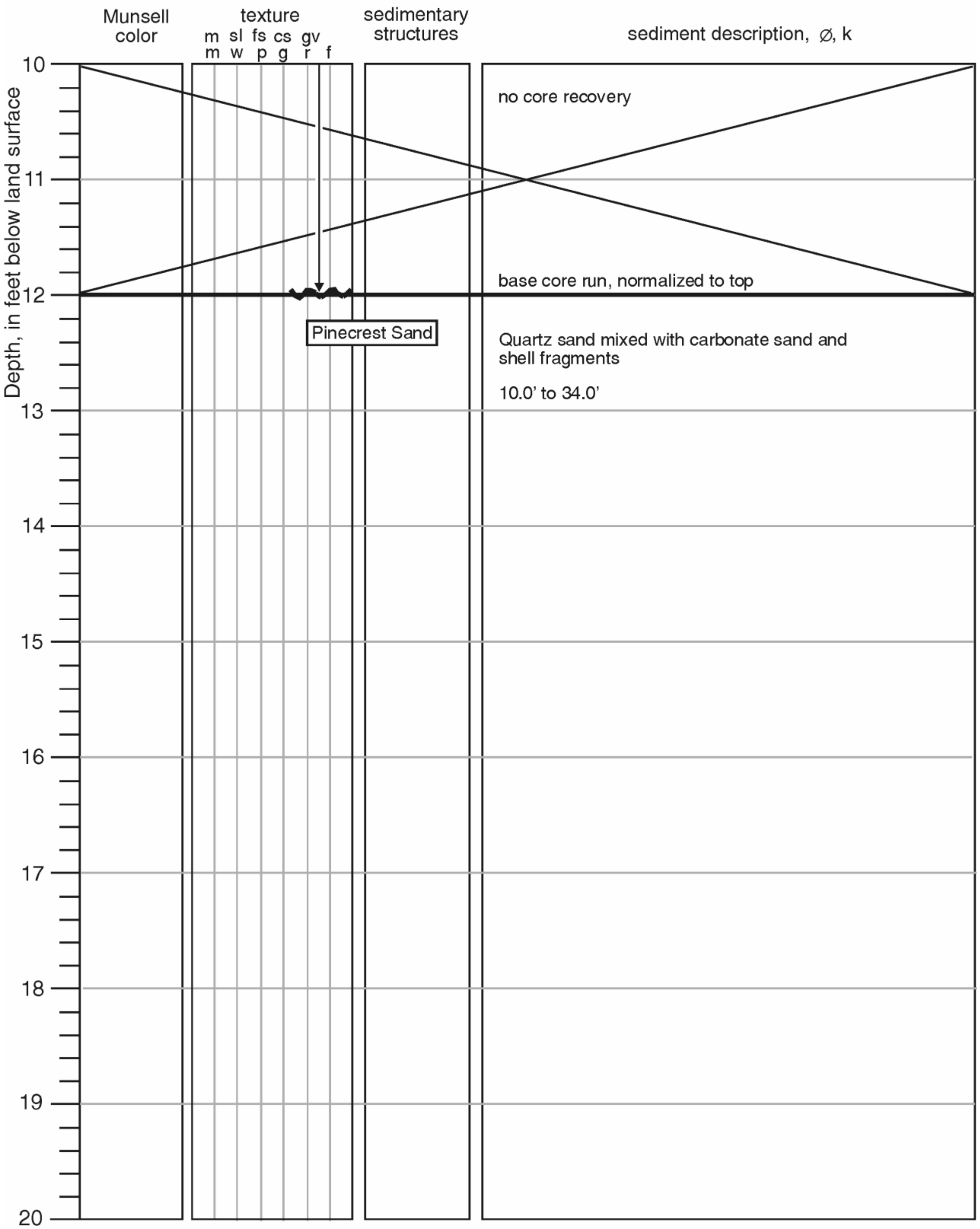
page **2** of **2**

Core 3AS3-GW-3

0-5.0'	Peat and Organic Sediment (not described).
5.00-5.50'	Lime Mudstone, massive lime mud, well cemented, possible root-hair molds, slight orange stain. Minor moldic porosity from roots, estimated <10%, low effective porosity. 10YR 8/3 very pale brown.
5.50'	Laminated Calcrete horizon.
5.50-6.25'	Lime Wackestone (Calcrete), lime mud as part of laminated calcrete mixed with minor amount of skeletal sand and lime mud host matrix. Bivalve fragments are the main skeletal allochem. Calcrete wackestone consists of horizontal laminated and vertical types, root structures common in lower part of interval. Interval has large molds and vugs, porosity is estimated at ~25%, high effective porosity. 2.5Y 8/2 pale yellow.
6.25-7.00'	No recovery, core normalized to top of run. Base of core run at 7.0'.
7.00-7.42	Lime Packstone and Grainstone. Skeletal sand with varying amounts (0-10%) of lime mud. Skeletal allochems mostly bivalves. Interval is leached producing moldic porosity, total porosity about 15-20%. Moderate to high effective porosity. 2.5Y 8/2 pale yellow (tan).
7.42-9.60'	Mixed Breccia and Oyster Floatstone with calcrete wackestone intervals. Interval consists of a skeletal limestone brecciated by subaerial exposure processes. Host limestone contains large (> 5 mm) oyster fragments in a matrix of lime mud and medium quartz sand. Modification through subaerial exposure produced brecciated fragments and blackened intraclasts. Interval is heavily leached producing vuggy porosity, total estimated at ~15-20%. Moderate effective porosity. Color is highly variable. Matrix is 2.5Y 8/2 pale yellow to 2.5Y 7/1 light gray.
9.60-12.00'	No recovery, core normalized to top of run. Base of core run at 12.0'.
12.0-34.0'	Quartz sand mixed with carbonate sand and shell fragments (not described).


Core 3AS3 - GW-3
Sheet 1 of 2
Date 3-25-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
0
1
2
3
4
5
6
7
8
9
10
peat and organic sediment
top rock
ts
10YR 8/3
v. pale brn.
Mudstone, dark brown lime mud, dense, poss. root molds, orange stain
2.5Y 8/2
pale
yellow
(tan)
Q4
Wackestone (calcrete)
-laminated lime mud as calcrete, both horiz. and vertical
-some skeletal sand as matrix, root molds
-vuggy, high effec. Ø
Q3b
Packstone-Grainstone, skeletal sands, moldic Ø
2.5Y 8/2
pale
yellow
Wackestone (calcrete) and breccia floatstone
-brecciated skeletal limestone containing quartz sand and lime mud-
-laminated calcrete at top of interval and as intraclasts
-contains some coarse to v. coarse quartz sand and oyster fragments
-intraclasts of cemented lime mud and calcrete, some blackened
-vuggy Ø
Q3a
F
2.5Y 7/1
light
gray
ts
base of recovered core
page 1 of 2

Core 3AS3 - GW-3 Sheet 2 of 2 Date 3-25-01



page 2 of 2

Core 3AS3-GW-4

0.0-3.50' Peat and Organic Sediment (not described).

3.50-4.50' Lime Packstone, peloids mixed with skeletal fragments and calcrete intraclasts. Moderately well cemented. Top of interval is likely a subaerial exposure surface, it is very well cemented and has evidence of a calcrete crust. Skeletal allochems in the matrix include bivalves and encrusting bryozoans. Some small, open vugs in lower part of interval, combined with interparticle porosity, give total porosity of 10-12%. Low to moderate effective porosity.
2.5Y 8/1 white (light tan) with 2.5Y 6/2 light brown-gray calcrete intraclasts.

4.50' Calcrete surface, likely related to subaerial exposure.

4.50-7.50' Lime Mudstone to Wackestone, lime mud with minor amounts (5-10%) of intraclasts related to soil breccia/blackened pebbles (6.4-7.0') or calcrete. Interval has root molds throughout, often vertically oriented. Upper part of interval has relatively low porosity (<10%), mainly moldic associated with vertical root structures. Middle and lower part of interval are more vuggy (core was rubble) and higher effective porosity.
2.5Y 8/1 white (tan) to 2.5YR 7/2 pale red staining in upper part of interval.

7.50-8.00' No recovery, core normalized to top of run. Base of core run at 8.0'.

8.00-8.25' Lime Packstone to Grainstone. Skeletal sand with minor amount of lime mud (<10%). Bivalve fragments is the dominant allochem. Moderately well cemented. Moldic and interparticle porosity at between 15-20%.
2.5Y 8/1 white (tan).

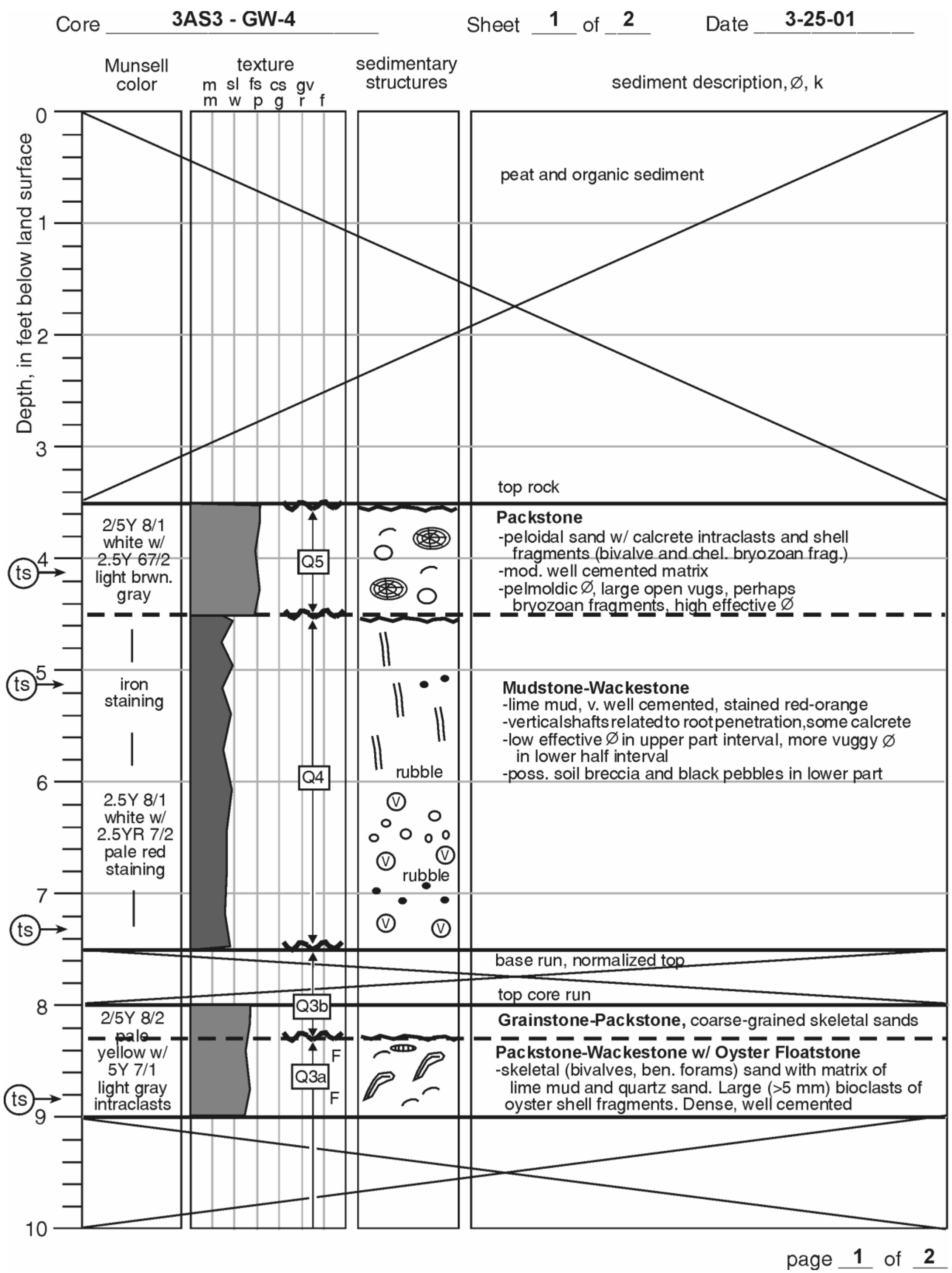
8.25-9.00' Intraclast-Oyster Floatstone with Lime Packstone to Wackestone matrix. Mixed lime sand and lime mud with quartz sand and intraclasts. Intraclasts (>5 mm) composed of oyster fragments in a quartz sand and lime mud matrix. Dense, well cemented.
Porosity is likely interparticle with some moldic, estimated at 10-15%.
2.5Y 8/2 pale yellow with 5Y 7/1 light gray intraclasts.

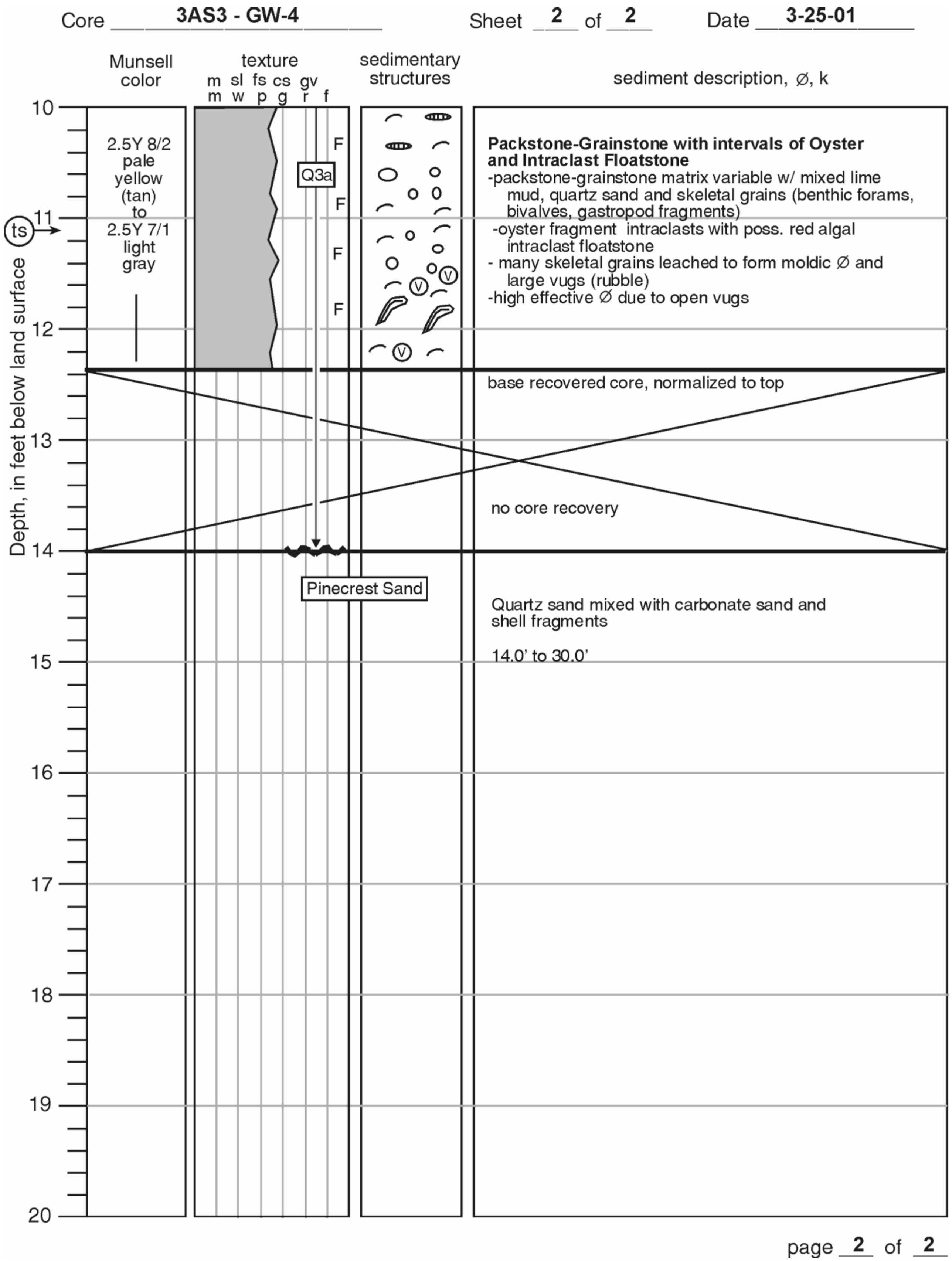
9.00-10.00' No recovery, core normalized to top of run. Base of core run at 10.0'.

10.00-12.33' Intraclast-Oyster Floatstone with Lime Packstone to Wackestone matrix, including possible rudstone interval throughout and some calcrete. Intraclasts have oyster shell fragments and possible red algal fragments in a matrix of mixed lime mud and medium quartz sand. Other allochems in the matrix include bivalve and gastropod fragments. Porosity is highly variable, some intervals have minor amounts of moldic porosity, while core rubble at ~11.6' indicates possible vuggy porosity. Overall effective porosity is moderate to high.
2.5Y 8/2 pale yellow to light gray.

12.33-14.00' No recovery, core normalized to top of run. Base of core run at 14'.

14.0-30.0' Quartz sand mixed with carbonate sand and shell fragments (not described).


Core 3AS3 - GW-4
Sheet 1 of 2
Date 3-25-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
0
1
2
3
4
5
6
7
8
9
10
peat and organic sediment
top rock
2/5Y 8/1 white w/ 2.5Y 67/2 light brwn. gray
ts
Q5
Packstone
-peloidal sand w/ calcrete intraclasts and shell fragments (bivalve and chel. bryozoan frag.)
-mod. well cemented matrix
-pelmoldic Ø, large open vugs, perhaps bryozoan fragments, high effective Ø
iron staining
ts
Mudstone-Wackestone
-lime mud, v. well cemented, stained red-orange
-verticalshaftsrelatedto rootpenetration,some calcrete
-low effective Ø in upper part interval, more vuggy Ø in lower half interval
-poss. soil breccia and black pebbles in lower part
rubble
Q4
2.5Y 8/1 white w/ 2.5YR 7/2 pale red staining
V
rubble
ts
base run, normalized top
top core run
Q3b
2/5Y 8/2 pale yellow w/ 5Y 7/1 light gray intraclasts
Grainstone-Packstone, coarse-grained skeletal sands
Packstone-Wackestone w/ Oyster Floatstone
-skeletal (bivalves, ben. forams) sand with matrix of lime mud and quartz sand. Large (>5 mm) bioclasts of oyster shell fragments. Dense, well cemented
F
Q3a
F
ts
page 1 of 2


Core 3AS3 - GW-4
Sheet 2 of 2
Date 3-25-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
2.5Y 8/2 pale yellow (tan) to 2.5Y 7/1 light gray
Q3a
F
F
F
F
ts
Packstone-Grainstone with intervals of Oyster and Intraclast Floatstone
-packstone-grainstone matrix variable w/ mixed lime mud, quartz sand and skeletal grains (benthic forams, bivalves, gastropod fragments)
-oyster fragment intraclasts with poss. red algal intraclast floatstone
- many skeletal grains leached to form moldic Ø and large vugs (rubble)
-high effective Ø due to open vugs
base recovered core, normalized to top
no core recovery
Pinecrest Sand
Quartz sand mixed with carbonate sand and shell fragments
14.0' to 30.0'
Depth, in feet below land surface
10
11
12
13
14
15
16
17
18
19
20
page 2 of 2

Core 3BS1-GW-1

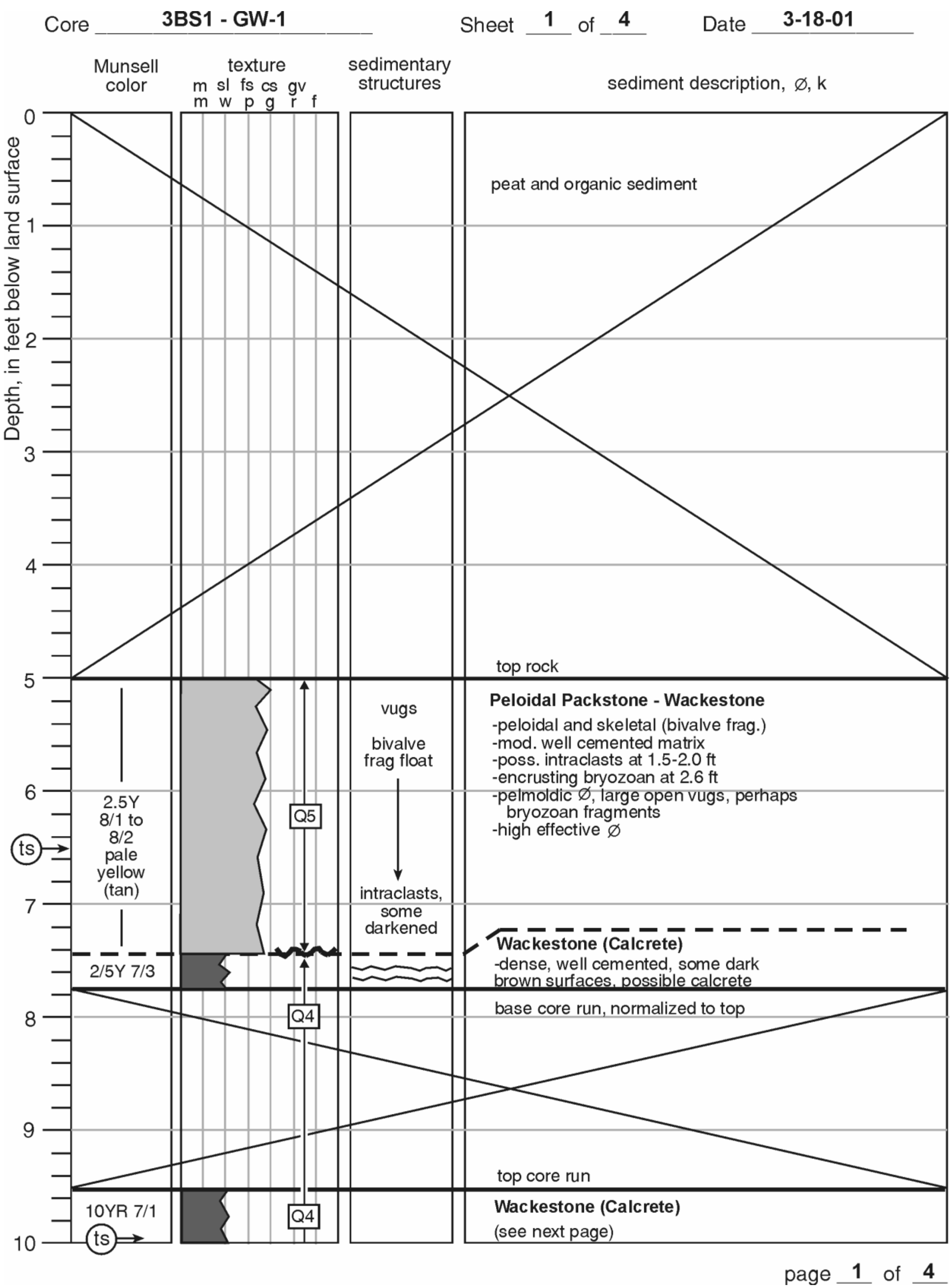
0 - 5.0'	Peat and Organic Sediment (not described).
5.0 - 7.42'	Grainstone-Packstone, mixed peloidal (60%) and bivalve allochems (5%) with varying amounts of lime mud matrix. Possible intraclasts at 6.5-7.0', possible encrusting bryozoan at 7.7'. Moderate well cemented. Porosity includes both pelmoldic in matrix and large open and partially filled vugs. Vugs perhaps related to bryozoan molds. Very high effective porosity. 2.5Y 8/1 to 8/2, pale yellow (tan).
7.42 - 7.75'	Lime Wackestone (calcrete), mud-rich interval with several dark-brown laminated horizons. Interval is dense, very well cemented. Porosity is <10% with a few small vugs and minor intraparticle. 2.5Y 7/3 pale yellow (tan with brown layers).
7.75-9.50'	No recovery, base of core run. Core normalized to run top.
9.50-10.40'	Lime Wackestone matrix with dark-brown laminated horizons (calcrete). Well cemented, dense. Lower half of interval appears brecciated with intraclasts, some darkened. Possible soil breccia. Porosity estimated at 15%, mostly vuggy Ø related to moldic dissolution. 5YR 7/2 pinkish gray (red-orange stained) with 10YR 7/1 light gray.
7.00-8	Lime Mudstone with red-orange staining. Mostly lime mud with calcrete laminations and some possible (soil?) breccia. Interval contains root molds and is dense and very well cemented. Low effective porosity, few isolated vugs with calcite infill. 5YR 7/2 pinkish gray (red-orange stained).
11.00-11.42'	Lime Wackestone, mixture of lime mud with >10% thin-walled bivalve fragments (as molds). Interval includes possible root molds, some infilled with LMC spar. <10% porosity due to some open molds, microporosity. Low effective porosity. 10YR 7/1 light gray (tan to very light brown).
11.42-11.80'	Lime packstone, bivalve fragments with some lime mud. Moderately well cemented. Many of the bivalve fragments are leached, yielding ~15% moldic porosity. 10YR 7/1 light gray (tan to very light brown).
11.80-12.50'	Mixed Lime Mudstone with thin Lime Wackestone intervals containing bivalve fragments. Wackestone units have moldic dissolution of bivalves allochems, mudstone units dense, well cemented. 10YR 7/1 light gray (tan to very light brown).
12.50'	Base of core run at 12.5'.
12.50-13.83'	Lime packstone, bivalve and gastropods fragments with occasional oyster fragment. Moldic porosity (15-20%) due to dissolution of mollusc allochems, moderate-high effective porosity. 10YR 7/1 light gray (tan to very light brown).

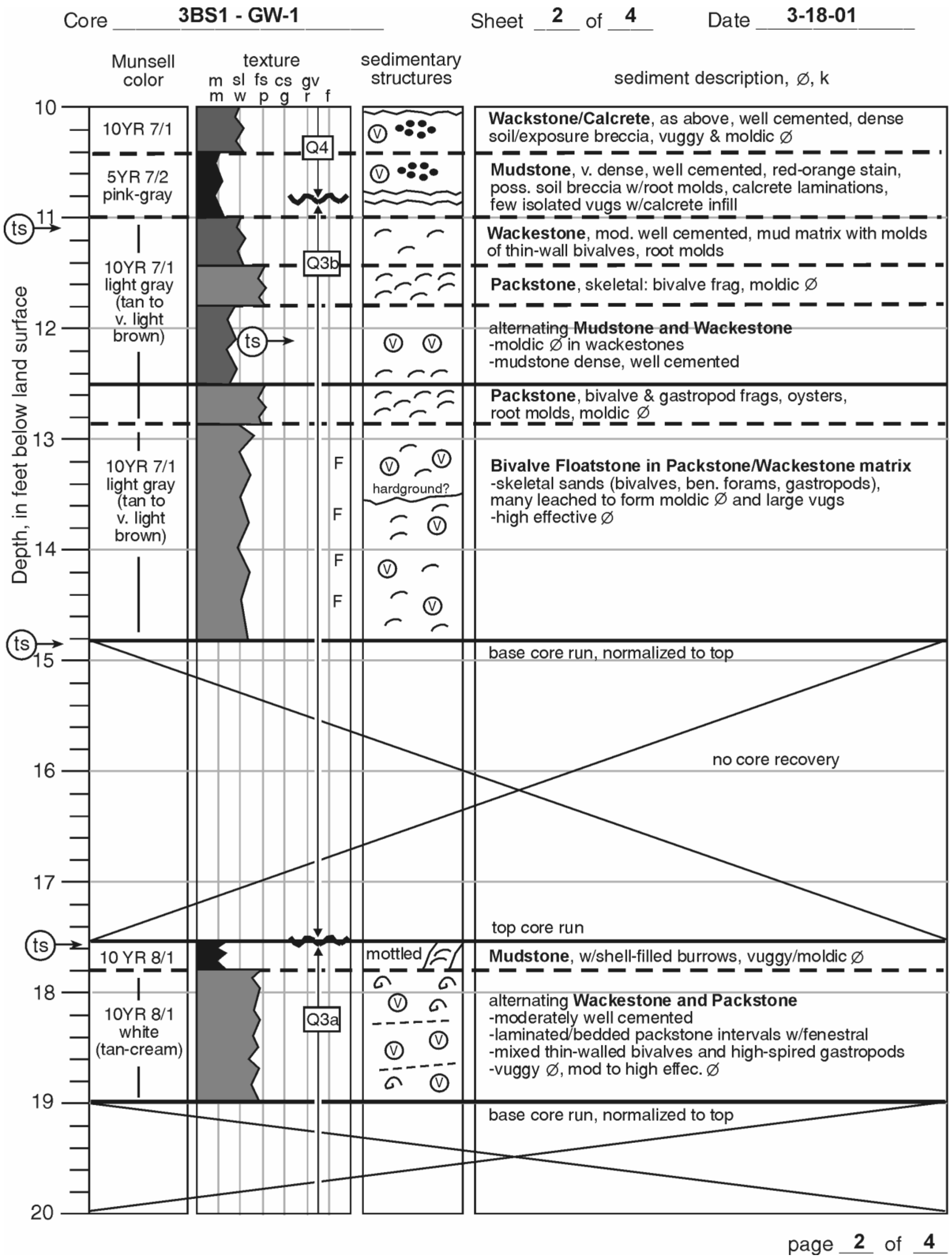
Core 3BS1-GW-1 - continued

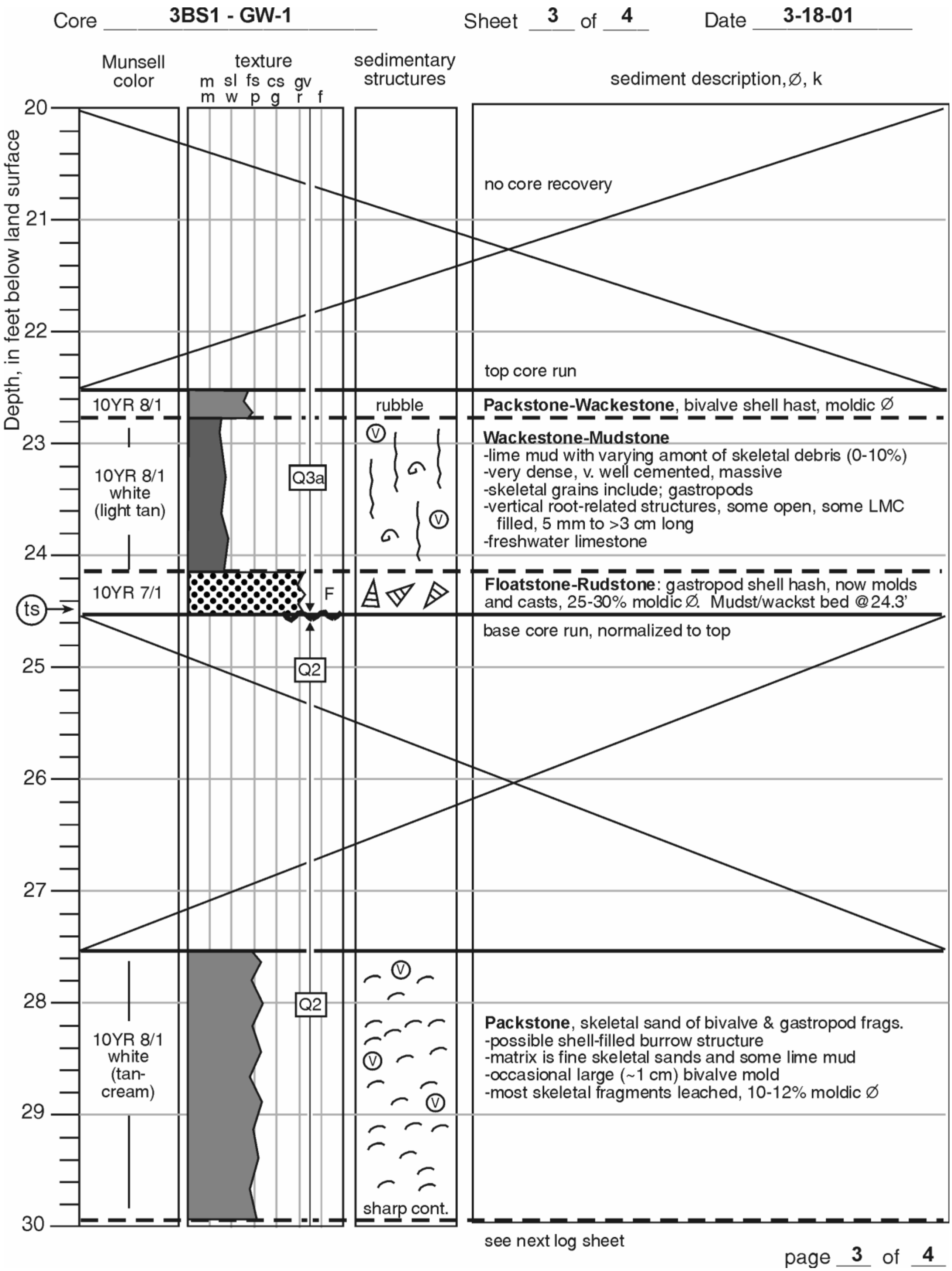
13.83-14.80'	Bivalve Floatstone in a Packstone to Wackestone matrix. Skeletal sands (bivalves, benthic foraminifers, gastropods) with varying amounts of lime mud in the matrix. Many skeletal allochems are leached, yielding moldic porosity and some large vugs. Total porosity is estimated at 15-20%. High effective porosity. 10YR 7/1 light gray (tan to very light brown).
14.80-17.50'	No recovery, core normalized to top of run. Base of core run at 17.50'.
17.5'	Possible hardground or subaerial exposure surface.
17.5-17.83'	Lime mudstone with shell-filled burrows. Burrows are mostly bivalve fragments with possible benthic foraminifers. Shell debris leached and burrows now friable and form vugs. Moldic porosity in burrow fills, otherwise mud-rich areas have relatively low effective porosity. 10YR 8/1 white (light tan).
17.83-19.90	Alternating Lime Wackestone and Packstone intervals. Packstone intervals laminated/bedded (possible beach facies) with fenestral porosity up to 30%. Skeletal allochems include bivalves and high-spired gastropods. Beside fenestral porosity in the packstone, those intervals also have some moldic porosity, overall estimated at 15-20%. Mudstone units have relatively low porosity. Interval is moderately well cemented. 10YR 8/1 white (light tan).
19.90-22.5'	No recovery, core normalized to top of run. Base of core run at 22.5'.
22.5'-22.75'	(rubble, possible drilling debris between core runs) Lime Packstone to Wackestone, bivalve shell hash with patches of lime wackestone (original fabric uncertain due to rubble). Skeletal allochems occur as either molds or casts, most leached. Moldic and vuggy porosity likely in undisturbed rock. 10YR 8/1 white (light tan).
22.75-24.10'	Lime Wackestone to Lime Mudstone. Lime mud with varying amounts of skeletal debris (0-10%). Skeletal allochems are mostly gastropods. Interval is very dense, very well cemented, massive. Contains some vertical root-related structures, some open and some filled with LMC spar. Root traces range from 5 mm to 3 cm long. Few horizontal fractures filled with LMC calcite. (likely a freshwater limestone deposit) 10YR 8/1 white (light tan)
24.10-24.50'	Gastropod Rudstone to Floatstone. Gastropod shell hash, now mainly molds and casts remaining, some up to 1 cm diameter. Matrix is mainly shell material with low lime mud, but contains a mud-rich interval at about 24.3'. Porosity is from 25-30% moldic, high to very high effective porosity. (*Planorbella* gastropod indicates a freshwater limestone deposit) 10YR 7/1 light gray (tan).
24.50-27.50'	No recovery, core normalized to top of run. Base of core run at 27.5'.

Core 3BS1-GW-1 - continued

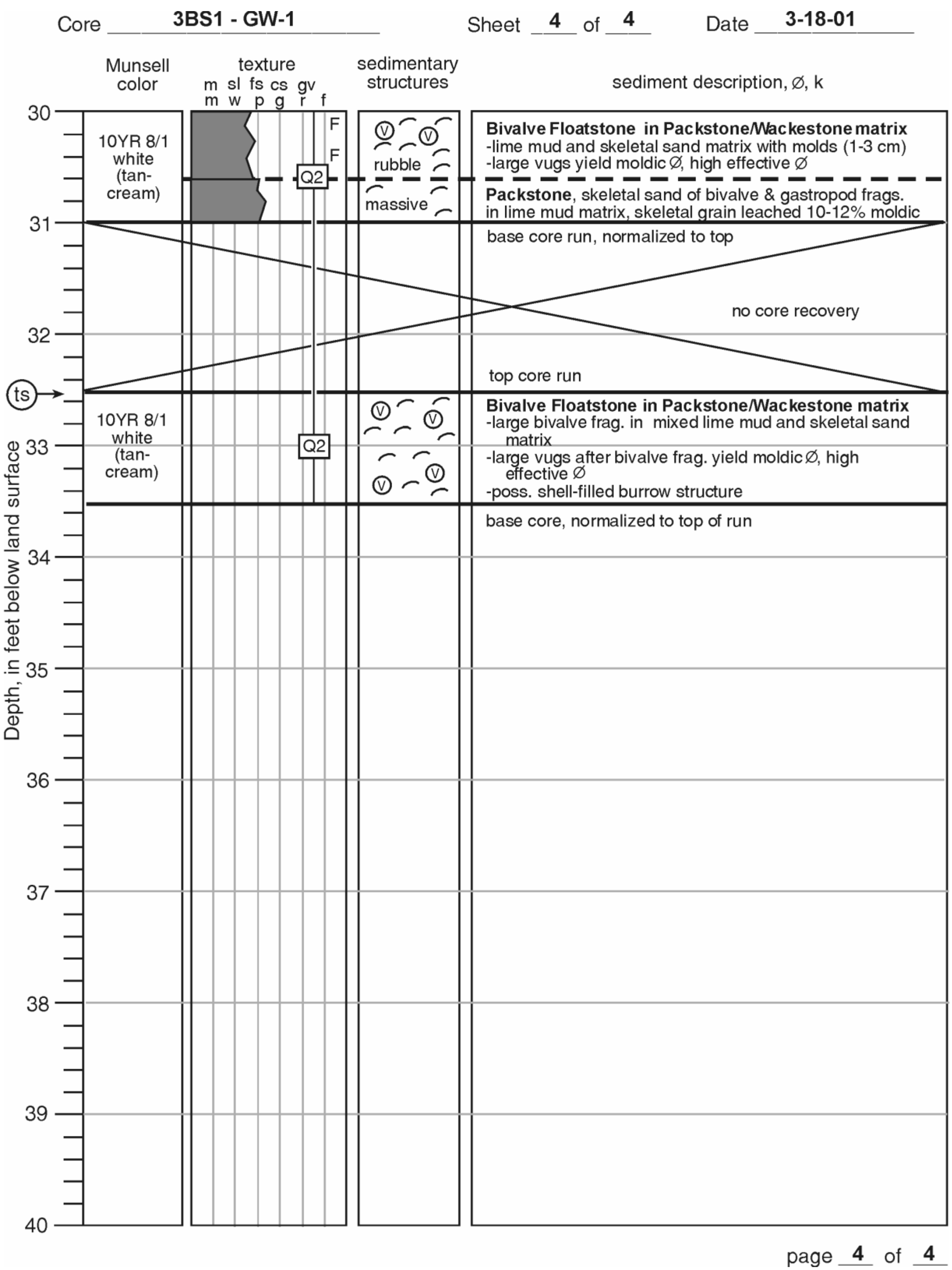
27.50-29.83'	Lime Packstone. Bivalve and gastropod skeletal sand in a matrix containing some lime mud. Interval contains possible shell-filled burrows. Occasional large (1 cm) bivalve mold or cast. Most skeletal fragments leached, moldic porosity in the range of 10-13%. Moderate effective porosity. 10YR 8/1 white (light tan).
29.83-30.60'	Bivalve Floatstone/Rudstone with a matrix of mixed skeletal sand and lime mud (packstone/wackestone). Large (>2mm) bivalve fragments some original shell material, or as cast/mold (1-3 cm long). Interval contains ~15% moldic/vug porosity, many large vugs from bivalve molds. 10YR 8/1 white (light tan).
30.60-31.00'	Lime Packstone. Same texture and color as interval 27.50-29.83'.
31.00-32.50'	No recovery, core normalized to top of run. Base of core run at 32.5'.
32.50-33.50'	Bivalve Floatstone with a matrix of mixed skeletal sand and lime mud (packstone-wackestone). Matrix is a mixture of fine skeletal sand and lime mud. Possible shell-filled burrows. Many bivalve fragments are leached and now yield moldic and vuggy porosity. Total porosity is estimated at 15-20%, moderate to high effective porosity. 10YR 8/1 white (light tan).
33.50'	Bottom of core.


Core 3BS1 - GW-1
Sheet 1 of 4
Date 3-18-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
0
1
2
3
4
5
6
7
8
9
10
peat and organic sediment
top rock
Peloidal Packstone - Wackestone
-peloidal and skeletal (bivalve frag.)
-mod. well cemented matrix
-poss. intraclasts at 1.5-2.0 ft
-encrusting bryozoan at 2.6 ft
-pelmoldic Ø, large open vugs, perhaps bryozoan fragments
-high effective Ø
vugs
bivalve frag float
intraclasts, some darkened
2.5Y 8/1 to 8/2 pale yellow (tan)
ts
Q5
Wackestone (Calcrete)
-dense, well cemented, some dark brown surfaces, possible calcrete
2/5Y 7/3
Q4
base core run, normalized to top
top core run
Wackestone (Calcrete)
(see next page)
10YR 7/1
ts
Q4
page 1 of 4


Core 3BS1 - GW-1
Sheet 2 of 4
Date 3-18-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
10
11
12
13
14
15
16
17
18
19
20
10YR 7/1
5YR 7/2 pink-gray
10YR 7/1 light gray (tan to v. light brown)
10YR 7/1 light gray (tan to v. light brown)
10 YR 8/1
10YR 8/1 white (tan-cream)
Q4
Q3b
Q3a
ts
F
hardground?
mottled
Wackstone/Calcrete, as above, well cemented, dense soil/exposure breccia, vuggy & moldic Ø
Mudstone, v. dense, well cemented, red-orange stain, poss. soil breccia w/root molds, calcrete laminations, few isolated vugs w/calcrete infill
Wackestone, mod. well cemented, mud matrix with molds of thin-wall bivalves, root molds
Packstone, skeletal: bivalve frag, moldic Ø
alternating Mudstone and Wackestone
-moldic Ø in wackestones
-mudstone dense, well cemented
Packstone, bivalve & gastropod frags, oysters, root molds, moldic Ø
Bivalve Floatstone in Packstone/Wackestone matrix
-skeletal sands (bivalves, ben. forams, gastropods), many leached to form moldic Ø and large vugs
-high effective Ø
base core run, normalized to top
no core recovery
top core run
Mudstone, w/shell-filled burrows, vuggy/moldic Ø
alternating Wackestone and Packstone
-moderately well cemented
-laminated/bedded packstone intervals w/fenestral
-mixed thin-walled bivalves and high-spired gastropods
-vuggy Ø, mod to high effec. Ø
base core run, normalized to top
page 2 of 4



Core 3BS1 - GW-1
Sheet 3 of 4
Date 3-18-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
20
21
22
23
24
25
26
27
28
29
30
no core recovery
top core run
10YR 8/1
rubble
Packstone-Wackestone, bivalve shell hast, moldic Ø
Wackestone-Mudstone
-lime mud with varying amont of skeletal debris (0-10%)
-very dense, v. well cemented, massive
-skeletal grains include; gastropods
-vertical root-related structures, some open, some LMC filled, 5 mm to >3 cm long
-freshwater limestone
10YR 8/1 white (light tan)
Q3a
10YR 7/1
F
ts
Floatstone-Rudstone: gastropod shell hash, now molds and casts, 25-30% moldic Ø. Mudst/wackst bed @24.3'
base core run, normalized to top
Q2
Q2
10YR 8/1 white (tan-cream)
Packstone, skeletal sand of bivalve & gastropod frags.
-possible shell-filled burrow structure
-matrix is fine skeletal sands and some lime mud
-occasional large (~1 cm) bivalve mold
-most skeletal fragments leached, 10-12% moldic Ø
sharp cont.
see next log sheet
page 3 of 4

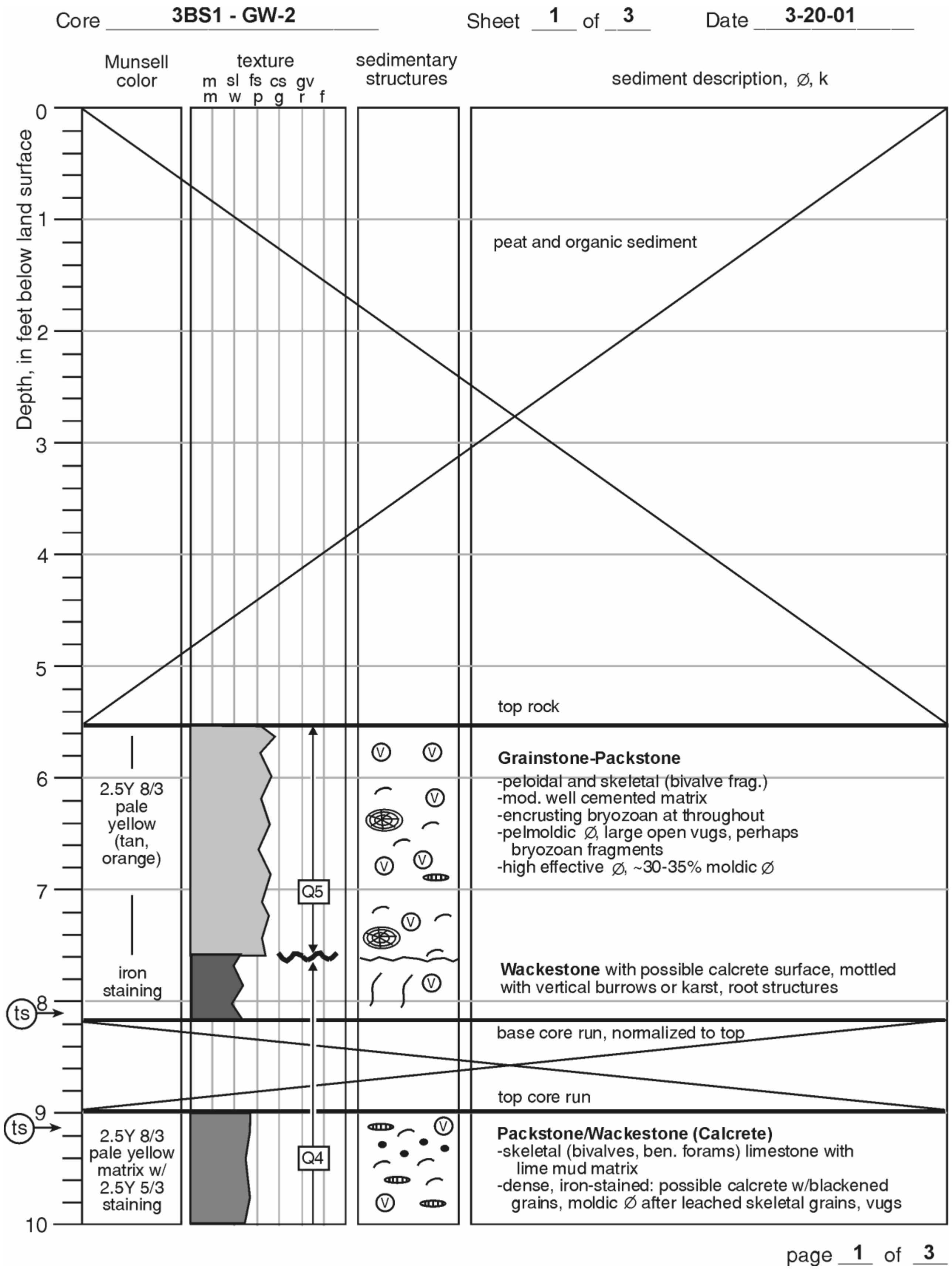

Core 3BS1 - GW-1
Sheet 4 of 4
Date 3-18-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
30
31
32
33
34
35
36
37
38
39
40
10YR 8/1 white (tan-cream)
F
F
Q2
rubble
massive
Bivalve Floatstone in Packstone/Wackestone matrix
-lime mud and skeletal sand matrix with molds (1-3 cm)
-large vugs yield moldic Ø, high effective Ø
Packstone, skeletal sand of bivalve & gastropod frags. in lime mud matrix, skeletal grain leached 10-12% moldic
base core run, normalized to top
no core recovery
top core run
ts
10YR 8/1 white (tan-cream)
Q2
Bivalve Floatstone in Packstone/Wackestone matrix
-large bivalve frag. in mixed lime mud and skeletal sand matrix
-large vugs after bivalve frag. yield moldic Ø, high effective Ø
-poss. shell-filled burrow structure
base core, normalized to top of run
page 4 of 4

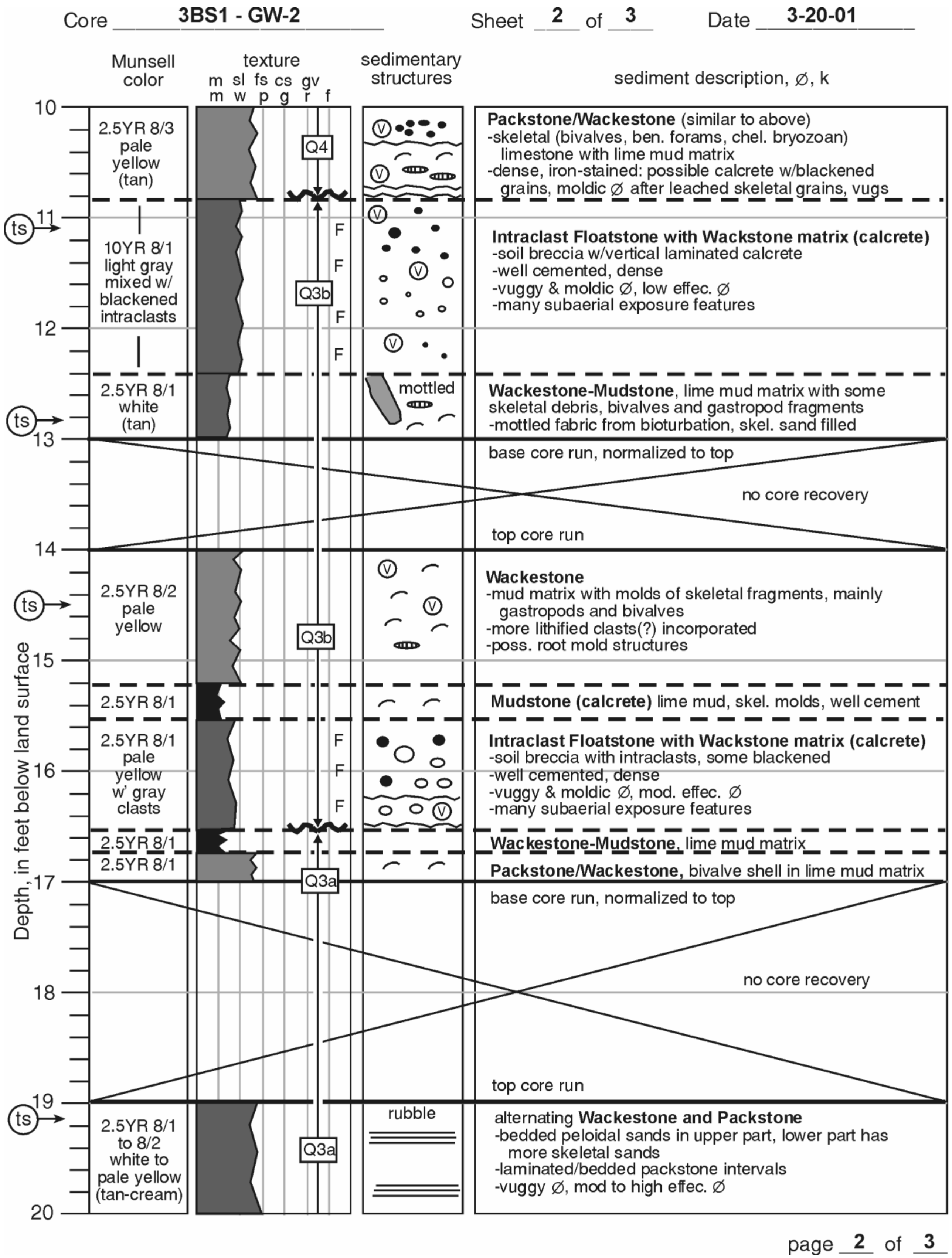
Core 3BS1-GW-2

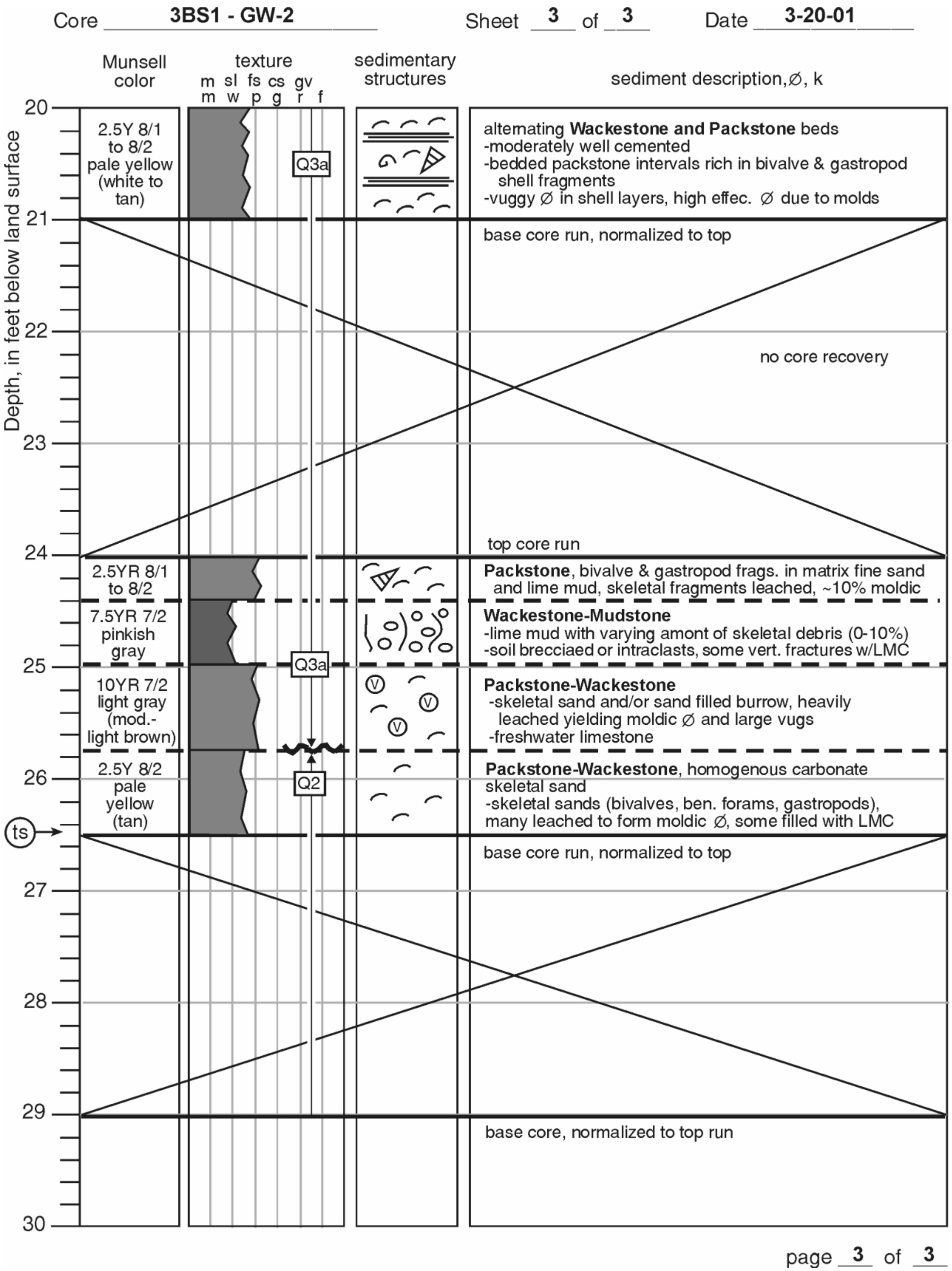
0-5.5'	Peat and Organic Sediment (not described).
5.5-7.60'	Grainstone - Packstone. Mixture of peloidal and skeletal grains with varying amounts of lime mud. Skeletal grains include bivalve fragments and encrusting bryozoans. Possible burrow structure below 7.5', filled with coarse skeletal sand. Bottom part of interval contains slightly high lime mud content and appears to be burrow mottled. Peloidal grains are leached and large open vugs have formed from the dissolution of the bryozoan fragments. Pelmoldic and vuggy porosity at ~30%, very high effective porosity. 2.5Y 8/3 pale yellow (tan, orange), some iron-staining in lower part of interval.
7.60-8.17'	Lime Wackestone with Calcrete. Mottled lime mud with vertical burrows and/or karst structures. Root structures. Original sediment likely modified by subaerial exposure processes. 2.5Y 8/3 pale yellow (tan) with some pink-orange oxidation staining.
8.17-9.00'	No recovery, core normalized to top of run. Base of core run at 9.0'.
9.00-10.80'	Lime Packstone. Skeletal carbonate sand consisting of bivalve, benthic foraminifers, encrusting bryozoan admixed with some lime mud. Interval is dense, very well cemented with red-orange staining and blackened grains/intraclasts. Possible calcrete horizon at ~10', orange-stained, laminated. Many skeletal grains are dissolved to give moldic porosity, some vugs. Large vug across contact with underlying lithologic unit. 2.5Y 8/3 pale yellow matrix with 2.5Y 5/3 light olive brown staining.
10.80-12.42'	Intraclast Floatstone with Wackestone (calcrete) matrix. Mud-rich wackestone texture (laminated calcrete) with breccia intraclasts likely related to subaerial exposure-related processes. Very dense, well cemented. Some open vugs, but with overall porosity probably <10%, low effective porosity. 10YR 8/1 white-pale brown with blackened grains, highly variable color.
12.42-13.00'	Lime Wackestone to Mudstone. Lime mud-rich texture with varying amounts of skeletal debris (gastropods and bivalves). Possible mottled fabric from burrowing, some burrows have more skeletal sand infill. Moldic porosity at ~10%, low effective porosity. 2.5Y 8/1 white (light tan).
13.00 14.00'	No recovery, core normalized to top of run. Base core run at 14.0'.
14.00-15.20'	Lime Wackestone. Lime mud matrix with some gastropod and bivalve allochems. Interval has differential cementation related to burrowing or perhaps due to intraclasts. Possible root-mold structures. 2.5Y 8/2 pale yellow (tan).
15.20-15.50'	Lime Mudstone (calcrete). Lime mud texture, mottled with few possible gastropod molds. Well cemented, dense. Minor moldic porosity from leached gastropod fragments. 2.5Y 8/1 white (light tan).

Core 3BS1-GW-2 - continued

15.50-16.50'	Intraclast Floatstone (Soil Breccia and Calcrete). Intraclasts (>2 mm) in a lime mud (wackestone) matrix likely related to subaerial exposure processes. Dense, very well cemented. Some moldic and interparticle porosity, overall ~10%. Low effective porosity. Much of the existing fabric related to subaerial exposure affects on a marine limestone. 2.5Y 8/1 white (tan) with black/gray intraclasts.
16.50-16.70'	Lime Mudstone to Wackestone. Lime-mud rich with varying amounts of skeletal (bivalve?) debris. Moderately well cemented. Low effective porosity. 2.5Y 8/1 white (light tan).
16.70-17.0'	Lime Packstone to Wackestone. Bivalve shell mixed with a lime mud matrix. Some moldic porosity associated with skeletal allochem leaching. 2.5Y 8/1 white (light tan).
17.00-19.00'	No recovery, core normalized to top of run. Base of core run at 19.0'.
19.00-20.00'	Alternating Lime Packstone to Wackestone. Mixed peloidal and skeletal (bivalve, benthic foraminifers) sand with varying amounts of lime mud. Upper part of interval has bedded peloidal(?) sands, lower part has coarse skeletal sands. Vuggy and intraparticle porosity at ~20%, moderate effective porosity. 2.5Y 8/1 to 8/2, white to pale yellow (light tan).
20.00-21.00'	Alternating Lime Packstone to Grainstone. Bivalve and gastropod shell hash with varying amounts of lime mud. Some skeletal grains leached, moldic porosity at ~20%, high effective porosity. 2.5Y 8/1 to 8/2 pale yellow (white to tan).
21.00-24.00'	No recovery, core normalized to top of run. Base of core run at 24.0'.
24.00-24.40'	(rubble) Lime Packstone. Skeletal (bivalve) sand with some lime mud. Bivalves and possible gastropods, benthic foraminifers as main allochems. Moldic dissolution of skeletal grains yield moldic/vuggy porosity. Estimated high effective porosity. 2.5Y 8/1 to 8/2 pale yellow (white to tan).
24.40-24.90'	Lime Wackestone to Mudstone. Lime mud rich with some minor skeletal allochems. Possible intraclasts or soil breccia. Some vertical fractures filled with LMC calcite. Dense, very well cemented. 7.5Y 7/2 pinkish gray (tan to light brown).
24.90-25.70'	(rubble) Lime Packstone. Bivalve skeletal debris and carbonate sand with lime mud. Large dissolution vugs from either burrows or leached skeletal debris. High effective porosity. 10YR 7/2 light gray (dark tan to light brown).
25.70-26.5'	Lime Packstone to Wackestone. Well sorted, fine-medium carbonate sand matrix with varying amounts of lime mud. Moderately well cemented. Larger skeletal grains leached, some filled with LMC. 5-8% moldic and interparticle porosity. 2.5Y 8/2 pale yellow (light tan).
26.5-29.00'	No recovery, core normalized to top of run. Bottom of core at 29.0'.


Core 3BS1 - GW-2
Sheet 1 of 3
Date 3-20-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
0
1
2
3
4
5
6
7
8
9
10
peat and organic sediment
top rock
2.5Y 8/3 pale yellow (tan, orange)
iron staining
Q5
Grainstone-Packstone
-peloidal and skeletal (bivalve frag.)
-mod. well cemented matrix
-encrusting bryozoan at throughout
-pelmoldic Ø, large open vugs, perhaps bryozoan fragments
-high effective Ø, ~30-35% moldic Ø
Wackestone with possible calcrete surface, mottled with vertical burrows or karst, root structures
ts
base core run, normalized to top
top core run
ts
2.5Y 8/3 pale yellow matrix w/ 2.5Y 5/3 staining
Q4
Packstone/Wackestone (Calcrete)
-skeletal (bivalves, ben. forams) limestone with lime mud matrix
-dense, iron-stained: possible calcrete w/blackened grains, moldic Ø after leached skeletal grains, vugs
page 1 of 3


Core 3BS1 - GW-2
Sheet 2 of 3
Date 3-20-01
Munsell color
texture
m m
sl w
fs p
cs g
gv r
f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
10
11
12
13
14
15
16
17
18
19
20
ts
ts
ts
ts
2.5YR 8/3 pale yellow (tan)
Q4
Packstone/Wackestone (similar to above)
-skeletal (bivalves, ben. forams, chel. bryozoan) limestone with lime mud matrix
-dense, iron-stained: possible calcrete w/blackened grains, moldic Ø after leached skeletal grains, vugs
10YR 8/1 light gray mixed w/ blackened intraclasts
F
F
F
F
Q3b
Intraclast Floatstone with Wackstone matrix (calcrete)
-soil breccia w/vertical laminated calcrete
-well cemented, dense
-vuggy & moldic Ø, low effec. Ø
-many subaerial exposure features
2.5YR 8/1 white (tan)
mottled
Wackestone-Mudstone, lime mud matrix with some skeletal debris, bivalves and gastropod fragments
-mottled fabric from bioturbation, skel. sand filled
base core run, normalized to top
no core recovery
top core run
2.5YR 8/2 pale yellow
Q3b
Wackestone
-mud matrix with molds of skeletal fragments, mainly gastropods and bivalves
-more lithified clasts(?) incorporated
-poss. root mold structures
2.5YR 8/1
Mudstone (calcrete) lime mud, skel. molds, well cement
2.5YR 8/1 pale yellow w' gray clasts
F
F
F
Intraclast Floatstone with Wackstone matrix (calcrete)
-soil breccia with intraclasts, some blackened
-well cemented, dense
-vuggy & moldic Ø, mod. effec. Ø
-many subaerial exposure features
2.5YR 8/1
Wackestone-Mudstone, lime mud matrix
2.5YR 8/1
Packstone/Wackestone, bivalve shell in lime mud matrix
Q3a
base core run, normalized to top
no core recovery
top core run
2.5YR 8/1 to 8/2 white to pale yellow (tan-cream)
Q3a
rubble
alternating Wackestone and Packstone
-bedded peloidal sands in upper part, lower part has more skeletal sands
-laminated/bedded packstone intervals
-vuggy Ø, mod to high effec. Ø
page 2 of 3



Core 3BS1 - GW-2
Sheet 3 of 3
Date 3-20-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description,∅, k
Depth, in feet below land surface
20
21
22
23
24
25
26
27
28
29
30
2.5Y 8/1 to 8/2 pale yellow (white to tan)
Q3a
alternating **Wackestone and Packstone** beds
-moderately well cemented
-bedded packstone intervals rich in bivalve & gastropod shell fragments
-vuggy ∅ in shell layers, high effec. ∅ due to molds
base core run, normalized to top
no core recovery
top core run
2.5YR 8/1 to 8/2
Packstone, bivalve & gastropod frags. in matrix fine sand and lime mud, skeletal fragments leached, ~10% moldic
7.5YR 7/2 pinkish gray
Wackestone-Mudstone
-lime mud with varying amont of skeletal debris (0-10%)
-soil brecciaed or intraclasts, some vert. fractures w/LMC
Q3a
10YR 7/2 light gray (mod.- light brown)
Packstone-Wackestone
-skeletal sand and/or sand filled burrow, heavily leached yielding moldic ∅ and large vugs
-freshwater limestone
Q2
2.5Y 8/2 pale yellow (tan)
Packstone-Wackestone, homogenous carbonate skeletal sand
-skeletal sands (bivalves, ben. forams, gastropods), many leached to form moldic ∅, some filled with LMC
ts
base core run, normalized to top
base core, normalized to top run
page 3 of 3

Core 3BS1-GW-3

0-5.50' Peat and Organic Sediment (not described).

5.50-7.50' Lime Packstone/Grainstone to Bryozoan Floatstone, mixed peloidal sand and skeletal allochems with minor lime mud concentration. Bryozoan fragments and bivalve fragments are main allochems. Base of interval has some brown intraclasts, likely reworked from underlying lithofacies. Peloids and bryozoans are both leached to produce pelmoldic and vuggy porosity, respectively. Total porosity is ~25%, high effective porosity.
10YR 8/2 very pale brown (tan to very light brown).

7.50' Sharp contact: disconformity.

7.50-9.33' Mixed Calcrete and Soil Breccia. Wackestone texture (calcrete) and intraclast floatstone (soil breccia). Light and dark laminated horizons, relatively dense, some small vugs occur in the upper half and base of the interval. The intermediate unit is a breccia with large intraclasts cemented in a dense matrix, interpreted to be a soil breccia related to subaerial exposure diagenetic processes. Overall porosity is <5%, few small, isolated vugs. Low effective porosity.
10YR 6/4 light yellow brown (wet) to 10YR 7/3 very pale brown (wet).

9.33-11.75' Lime Wackestone to Packstone, lime-mud matrix with fine-grained skeletal fragments including bivalves and benthic foraminifers. Unit appears to be burrowed with coarse sand infills and may also have small intraclasts. Upper part has brown-stained subvertical shafts possible related to penetrative root or calcrete development. Porosity in the undisturbed parts appears to be interparticle. The rubble intervals may have more vuggy porosity.
2.5Y 7/1 light gray.

11.75-12.50' No recovery, core normalized to top of run. Base of core run at 12.5'.

12.50-14.00' Lime Wackestone to Packstone (similar to 9.33-11.75') with some intervals of bivalve rudstone. Mixed skeletal allochems (bivalves, benthic foraminifers) and lime mud. Possible burrow structures. Moderately well cemented with some vugs (0.5-1.0 cm). Porosity is a mix of vuggy and interparticle porosity, estimated at 20%.
2.5Y 7/1 light gray.

14.00-15.25' Alternating Mudstone/Wackestone units and packstone/grainstone lithology. Bedded packstone/grainstone with beds of lime mud (wackestone). Skeletal debris in coarse-grained units includes bivalves, gastropods, benthic foraminifers. Sand intervals leached, porosity a combination of interparticle and moldic porosity at ~15%.
2.5Y 8/1 white (light tan).

15.25-17.50' No recovery, core normalized to top of run. Base of core run at 17.5'.

Core 3BS1-GW-3 - continued

17.50-18.33' Lime Packstone to Wackestone, skeletal allochems mixed with varying amounts of lime mud. Main skeletal allochem are bivalve fragments. Possible calcrete or calcrete intraclast at top of core (possibly drilling rubble cave-in). Unit has moldic porosity with some large (1-2 cm), open vugs with porosity estimated at ~25%. Very high effective porosity.
2.5Y 8/1 to 8/2 white-pale yellow (light tan).

18.33-21.5' No recovery, core normalized to top of run. Base of core run at 21.5'.

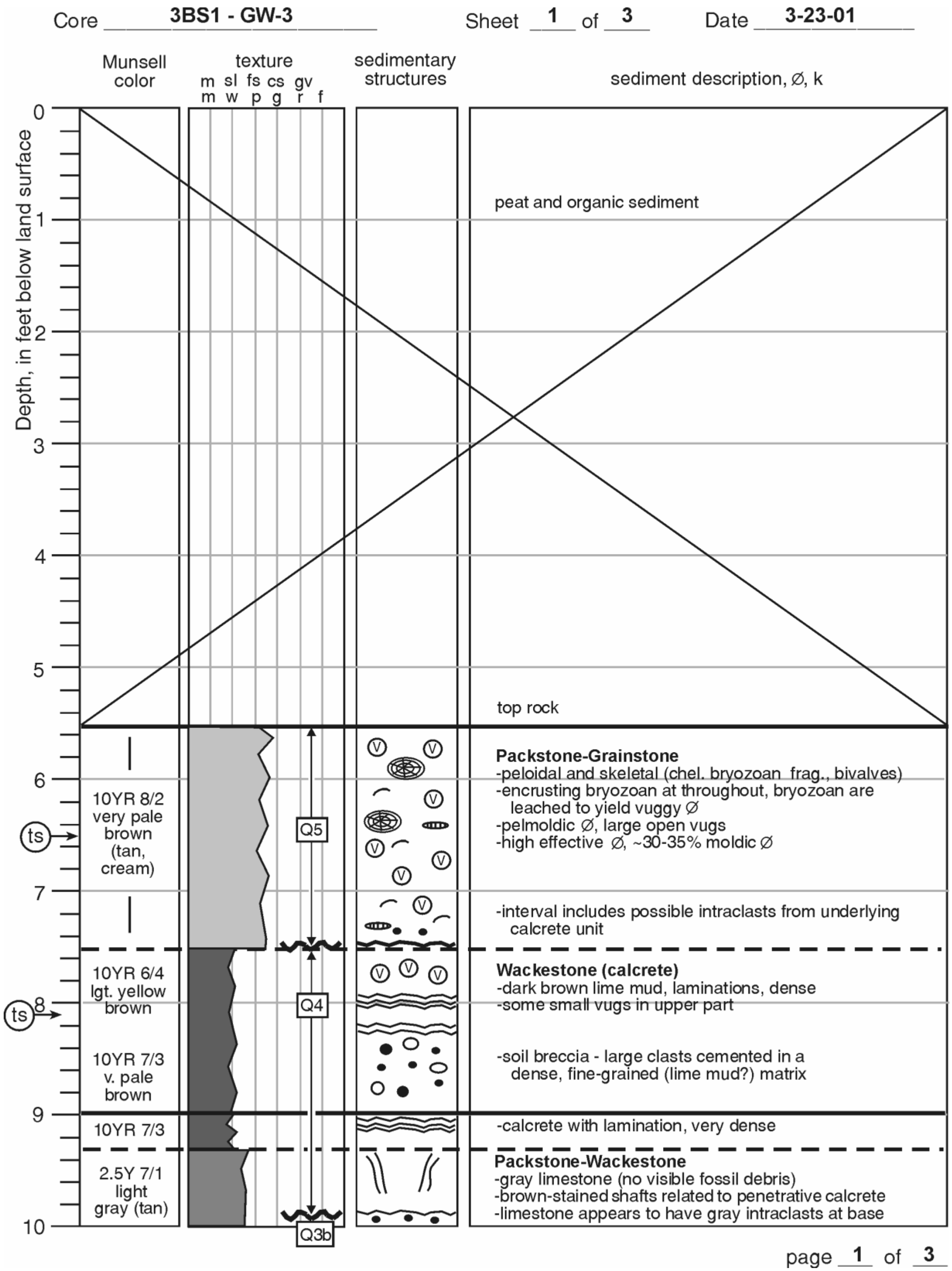
21.5-22.60' Lime Wackestone-Mudstone, cemented lime mud, partially brecciated and cemented with calcite. Less brecciated downward, relatively dense. Some vuggy and interparticle porosity (5-10%). Low effective porosity.
(likely freshwater limestone).
2.5Y 7/2 light gray (very light brown). Transition to underlying unit:

22.60-23.90' Lime Packstone to Wackestone, gastropod and bivalve allochems (some leached) mixed with varying amounts of lime mud matrix. Leached skeletal allochems yield moldic porosity (10-15%).
(likely freshwater limestone).
2.5Y 7/2 light gray (light brown). Sharp contact to underlying unit.

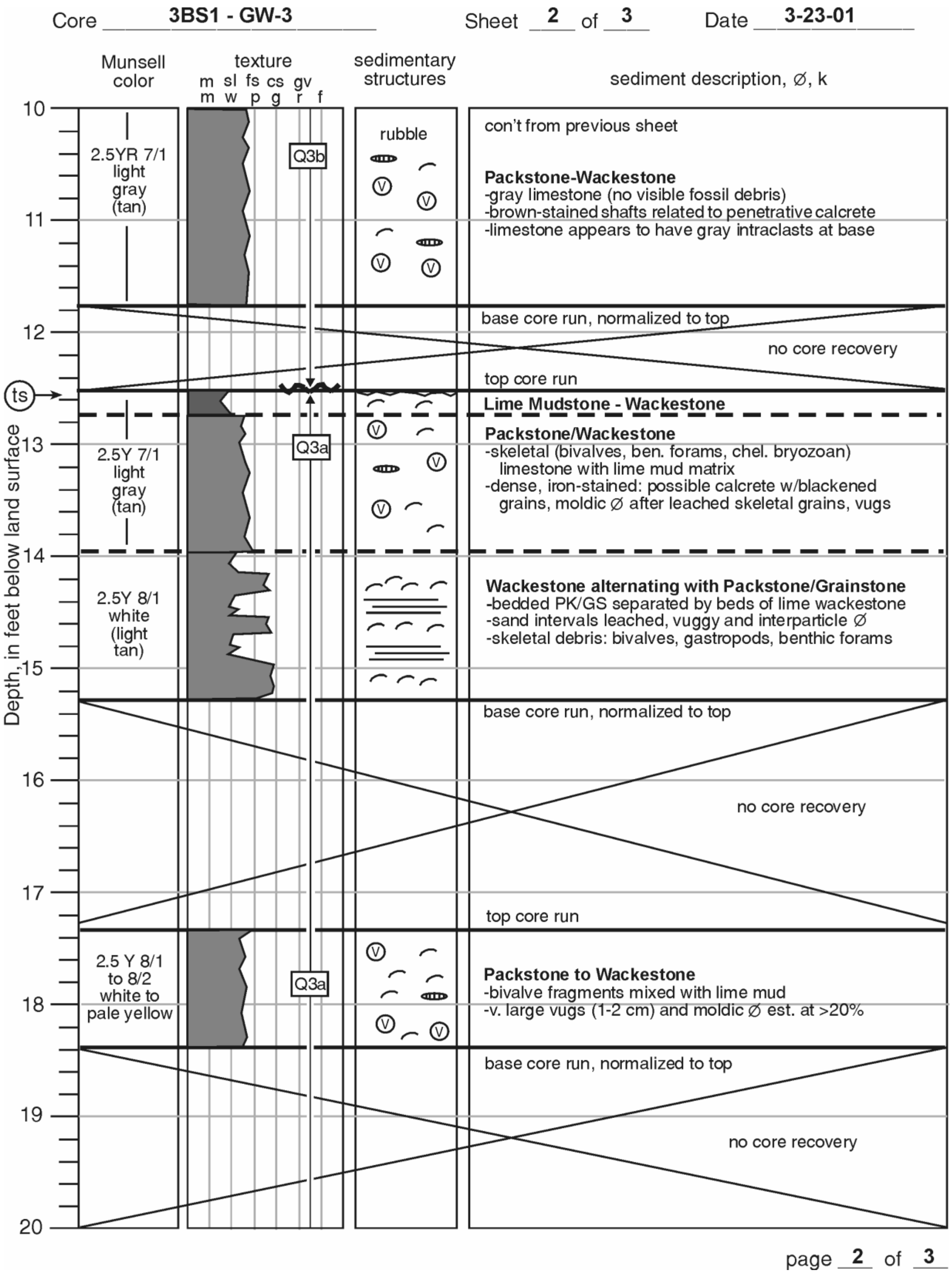
23.90-26.50' Lime Packstone, skeletal allochems with minor amount of lime mud. Well-sorted skeletal sand unit with bivalve, gastropod, benthic foraminifers as the main allochems. Moderately well cemented. Porosity is a combination of moldic and interparticle estimated at between 10-15%. Moderate effective porosity.
2.5Y 8/2 pale yellow (light tan).

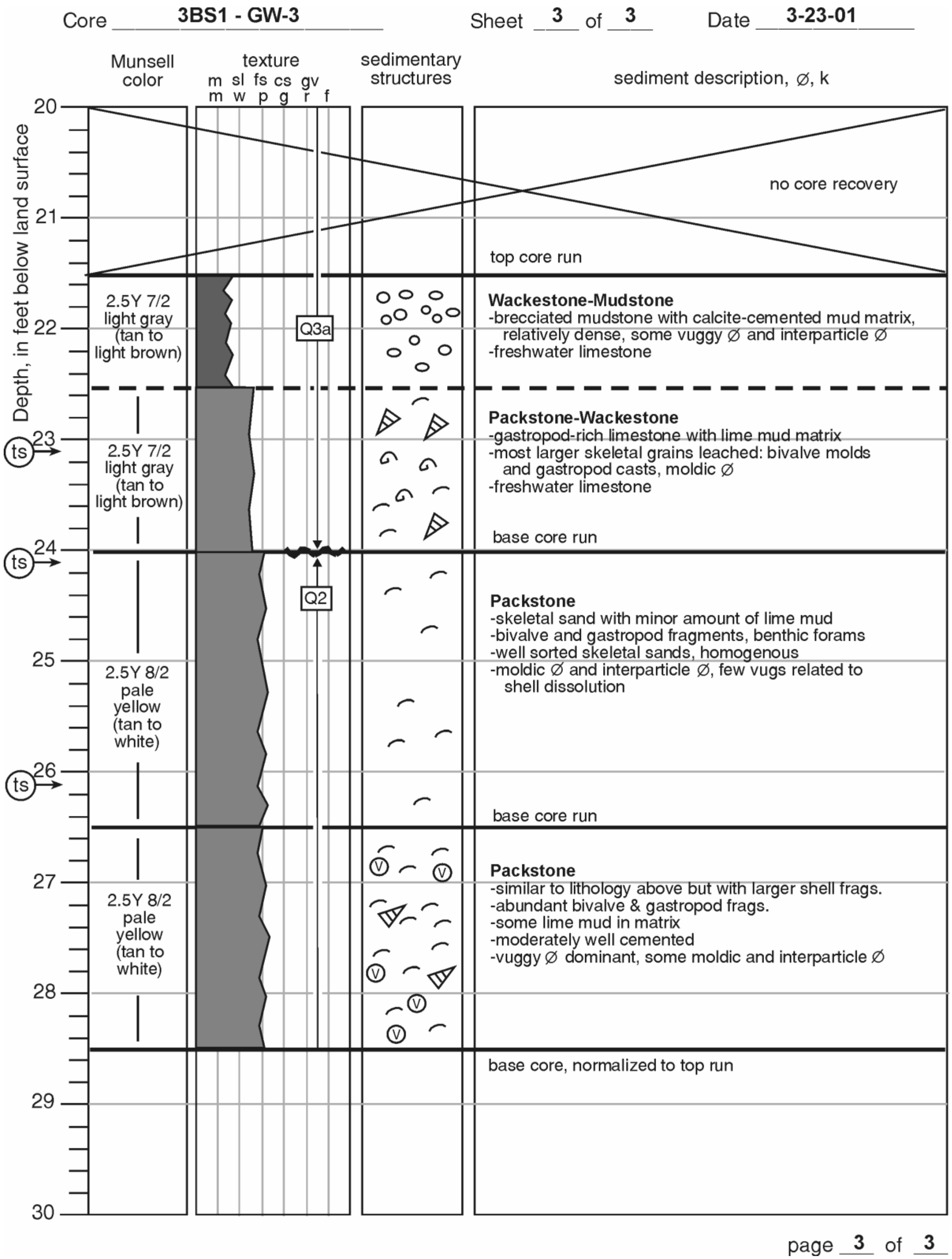
26.50-28.5' (rubble) Lime Packstone (similar to above lithology but with larger shell fragments), abundant bivalve and gastropod fragments with minor amount of lime mud. Moderate to well cemented. Porosity was likely vuggy due to rubble condition of the recovered rock (no porosity estimate).
2.5Y 8/2 pale yellow (light tan).

28.5' Bottom of core.



Core 3BS1 - GW-3
Sheet 1 of 3
Date 3-23-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
0
1
2
3
4
5
6
7
8
9
10
peat and organic sediment
top rock
10YR 8/2 very pale brown (tan, cream)
ts
Q5
Packstone-Grainstone
-peloidal and skeletal (chel. bryozoan frag., bivalves)
-encrusting bryozoan at throughout, bryozoan are leached to yield vuggy Ø
-pelmoldic Ø, large open vugs
-high effective Ø, ~30-35% moldic Ø
-interval includes possible intraclasts from underlying calcrete unit
10YR 6/4 lgt. yellow brown
ts
Q4
Wackestone (calcrete)
-dark brown lime mud, laminations, dense
-some small vugs in upper part
10YR 7/3 v. pale brown
-soil breccia - large clasts cemented in a dense, fine-grained (lime mud?) matrix
10YR 7/3
-calcrete with lamination, very dense
2.5Y 7/1 light gray (tan)
Packstone-Wackestone
-gray limestone (no visible fossil debris)
-brown-stained shafts related to penetrative calcrete
-limestone appears to have gray intraclasts at base
Q3b
page 1 of 3


Core 3BS1 - GW-3
Sheet 2 of 3
Date 3-23-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
10
11
12
13
14
15
16
17
18
19
20
Depth, in feet below land surface
ts
2.5YR 7/1 light gray (tan)
Q3b
rubble
con't from previous sheet
Packstone-Wackestone
-gray limestone (no visible fossil debris)
-brown-stained shafts related to penetrative calcrete
-limestone appears to have gray intraclasts at base
base core run, normalized to top
no core recovery
top core run
Lime Mudstone - Wackestone
2.5Y 7/1 light gray (tan)
Q3a
Packstone/Wackestone
-skeletal (bivalves, ben. forams, chel. bryozoan) limestone with lime mud matrix
-dense, iron-stained: possible calcrete w/blackened grains, moldic Ø after leached skeletal grains, vugs
2.5Y 8/1 white (light tan)
Wackestone alternating with Packstone/Grainstone
-bedded PK/GS separated by beds of lime wackestone
-sand intervals leached, vuggy and interparticle Ø
-skeletal debris: bivalves, gastropods, benthic forams
base core run, normalized to top
no core recovery
top core run
2.5 Y 8/1 to 8/2 white to pale yellow
Q3a
Packstone to Wackestone
-bivalve fragments mixed with lime mud
-v. large vugs (1-2 cm) and moldic Ø est. at >20%
base core run, normalized to top
no core recovery
page 2 of 3


Core 3BS1 - GW-3
Sheet 3 of 3
Date 3-23-01
Munsell color
texture
m m
sl w
fs p
cs g
gv r
f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
20
21
22
23
24
25
26
27
28
29
30
ts
ts
ts
no core recovery
top core run
2.5Y 7/2 light gray (tan to light brown)
Q3a
Wackestone-Mudstone
-brecciated mudstone with calcite-cemented mud matrix, relatively dense, some vuggy Ø and interparticle Ø
-freshwater limestone
2.5Y 7/2 light gray (tan to light brown)
Packstone-Wackestone
-gastropod-rich limestone with lime mud matrix
-most larger skeletal grains leached: bivalve molds and gastropod casts, moldic Ø
-freshwater limestone
base core run
Q2
2.5Y 8/2 pale yellow (tan to white)
Packstone
-skeletal sand with minor amount of lime mud
-bivalve and gastropod fragments, benthic forams
-well sorted skeletal sands, homogenous
-moldic Ø and interparticle Ø, few vugs related to shell dissolution
base core run
2.5Y 8/2 pale yellow (tan to white)
Packstone
-similar to lithology above but with larger shell frags.
-abundant bivalve & gastropod frags.
-some lime mud in matrix
-moderately well cemented
-vuggy Ø dominant, some moldic and interparticle Ø
base core, normalized to top run
page 3 of 3

Core 3BS1-GW-4

0-8.50'	Peat and Organic Sediment (not described). (bags of rubble labeled 8'-9' and 8'-10' in the top of core box) Lime Packstone, peloidal and skeletal allochems, bryozoan fragments.
8.50-9.92'	Packstone-Grainstone, mixed peloids and skeletal allochems with <10% lime mud. Main allochems are bivalves and benthic foraminifers. Matrix is moderately cemented. Porosity is pelmoldic and vuggy, total porosity is ~15-20%. Vugs 0.5-1.5 cm diameter, very high effective porosity. Calcrete at base of interval. 2.5Y 7/2 light gray (light tan).
9.92-12.50'	No recovery, core normalized to top of run. Base of core run at 12.5'.
12.50-15.42'	Alternating Lime Packstone-Grainstone with intervals of Intraclast Floatstone. Packstone-grainstone contain encrusting bryozoan, benthic foraminifers, and bivalve fragments with variable amounts of lime mud. The intraclast floatstone consists of lime wackestone clasts, often blackened ranging in size from 0.5 to ~2.0 cm. Moldic, vuggy, and interparticle porosity at 15-20%. Interval has high effective porosity due to open vugs/molds and weakly cemented (friable) matrix. Interval likely modified by subaerial exposure processes (soil breccia). Calcrete at bottom contact. Mixed 7.5 YR 5/4 light brown and 7.5YR 7/1 light gray.
15.42-15.90'	Lime Packstone to Wackestone, massive gray limestone, likely mixed of fine skeletal material and lime mud. Greater percent skeletal allochems at base of interval with small bivalve molds. Alternatively, basal part of interval may be an intraclast rudstone (difficult to confirm in core). Moderately well cemented. Likely interparticle porosity, estimated at ~10%. Moderate to low effective porosity. 10YR 7/1 light gray.
15.90-16.50'	No recovery, core normalized to top of run. Base of core run at 16.5'.
16.50-17.00'	Lime Packstone to Wackestone, bivalve-rich skeletal limestone with lime mud matrix of variable amount. Interval is moderately well cemented. Moldic porosity estimated at 10-15%. Moderate to high effective porosity. 10YR 7/2 light gray (tan). Base of interval contains a laminated lime wackestone (laminated calcrete related to subaerial exposure processes).
17.00-17.80'	Lime Wackestone (Calcrete) to Intraclast Floatstone, lime mud with laminated calcrete (upper part) containing large intraclasts as part of a soil breccia (lower part). Interval is well cemented, moderate to low effective porosity. Calcrete: 10YR 6/3 pale brown.
17.80-18.50'	No recovery, core normalized to top of run. Base of core run at 18.5'.

Core 3BS1-GW-4 - continued

18.50-20.40' Lime Wackestone to Packstone, fine-grained skeletal(?) sand with differing amounts of lime mud. Sediment has been likely burrowed and/or modified by root penetration to produce a differentially cemented fabric. More mud-rich intervals appear to be more cemented relative to the packstone texture. Interval contains small (1-4 mm) blackened intraclasts, although no evidence of subaerial exposure is evident. Interparticle porosity in packstone textures, overall estimate at 10-15%.
10YR 7/1 light gray.

20.40-21.00' No recovery, core normalized to top of run. Base of core run at 21.0'.

21.00-23.60' Lime Wackestone to Mudstone,
(upper part 21.0-22.6') massive lime mud with some evidence of bivalve fragments (~10%). Lime mud is partially brecciated and may have some molds associated with small roots or root hairs. Skeletal allochems dissolved away to produce moldic porosity, with vertical root molds estimated at 5-10%. Low effective porosity.
10YR 7/1 light gray.
(middle part, 22.6-22.8') laminated fine sand and lime mud.
10YR 7/1 light gray.
(lower part 22.8-23.6') lime mud with bivalve and gastropod allochems, possibly burrowed, also contains nodule-type features of unknown (algal?) origin. Skeletal allochems are leached to produce some moldic porosity. Porosity estimated at <10%, low effective porosity.
10YR 7/2 light gray (light brown to tan).

23.60-24.00' Grainstone, bedded, coarse skeletal sand consisting of mainly bivalve fragments. Moderate to well cemented. Interparticle porosity at ~15%.
10YR 7/1 light gray (tan).

24.00-27.00' Lime Packstone, bivalve fragments and benthic foraminifers mixed with minor amount of lime mud (10-15%). Moderately well cemented. Differential cementation with finer-grained fabric well cemented and coarse-grained parts friable producing large interconnected vugs. Vuggy and interparticle porosity at ~20%, high effective porosity.
10YR 7/1 light gray (tan).

27.00-27.33' Lime Wackestone, lime mud with 10-15% skeletal (bivalve) allochems. Few open vertical vugs related to either roots or burrow structures. Moldic porosity about 5-7%, low effective porosity.
10YR 8/2 very pale brown.

27.33-30.00' No recovery, core normalized to top of run. Base of core run at 30.0'.

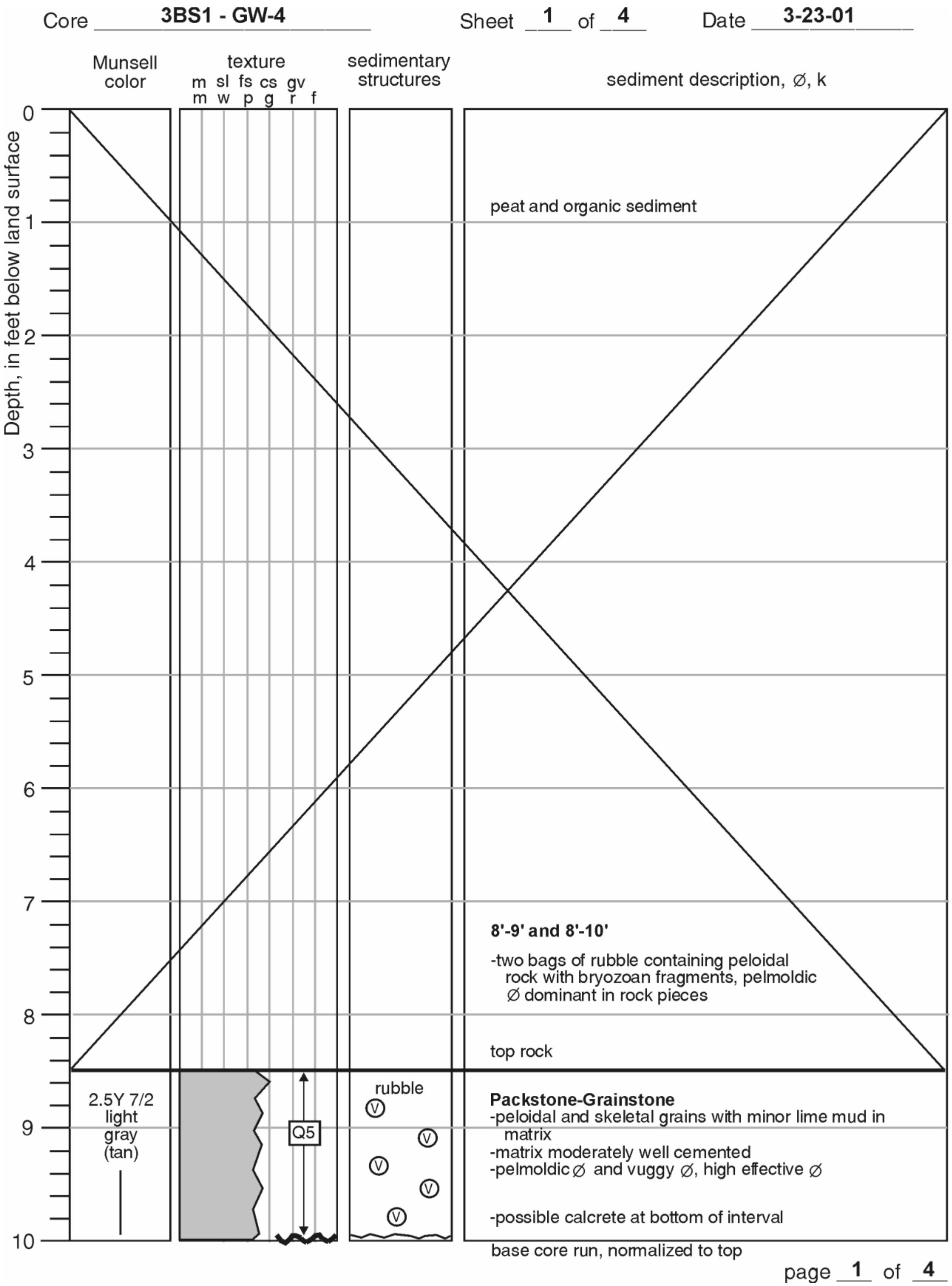
Core 3BS1-GW-4 - continued

30.00-31.40' Lime Mudstone to Wackestone, lime mud matrix with variable amount of skeletal allochems 2-10%. Possible burrow structures give rise to open vertical shafts 5-8 mm in diameter. Root molds also form small vugs and vertical shafts (~1 mm diameter). Moldic and vuggy porosity estimated at ~6-10%, but low effective porosity. Possible freshwater limestone.
2.5Y 8/1 white (light tan).

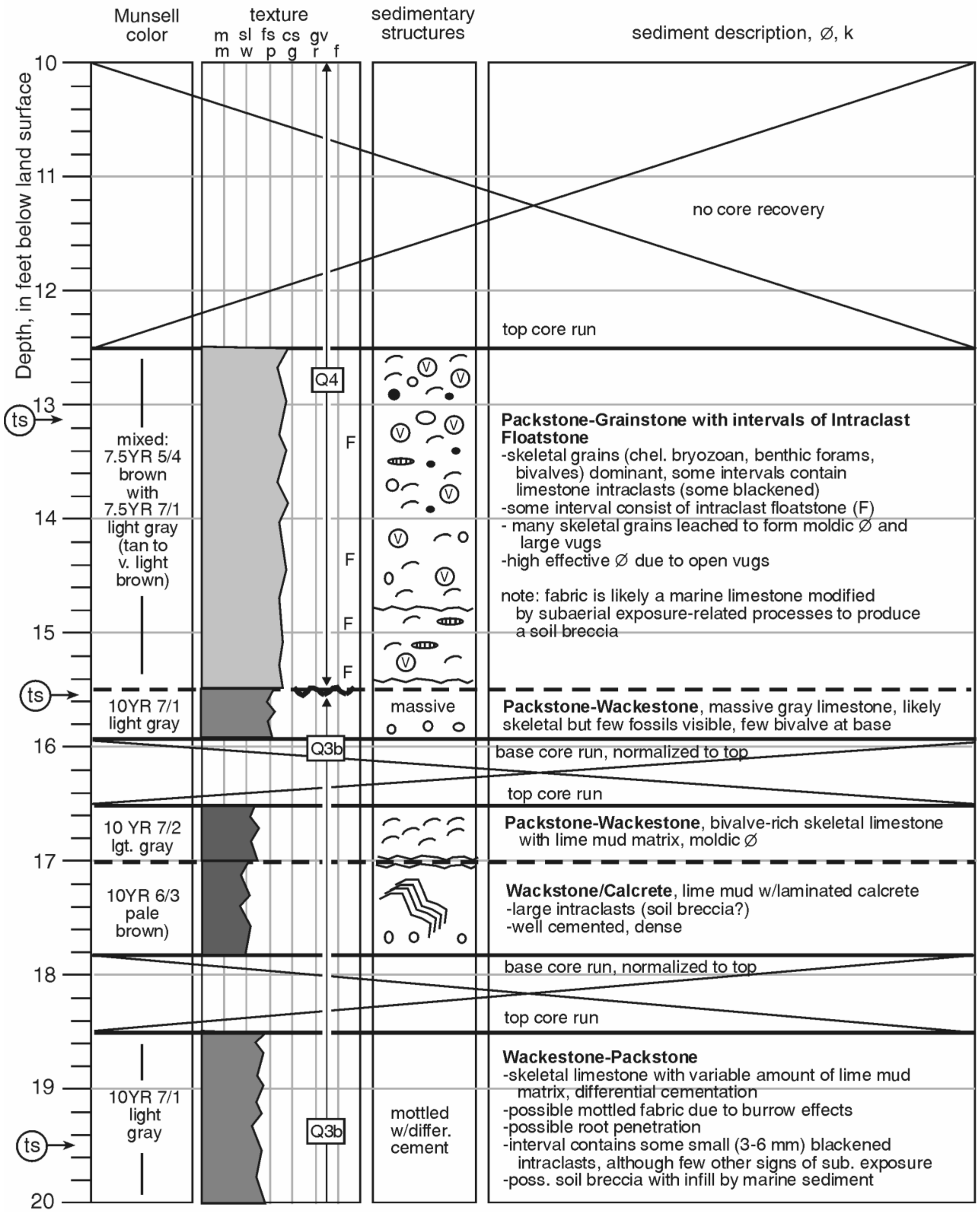
31.40-32.00' Lime Wackestone to Packstone, gastropod allochems mixed with lime mud matrix ranging from 10-205. Skeletal allochems often leached to give moldic porosity (~10%), and low effective porosity. Likely freshwater limestone.
2.5Y 7/1 to 8/1 white (light tan).

32.00-35.00' Lime Packstone, well-sorted skeletal sands mixed with minor amount of lime mud (~10%). Visible skeletal allochems include bivalve fragments and benthic foraminifers. Moderately well cemented. Moldic and interparticle porosity at ~7-10%. Moderate effective porosity.
2.5Y 8/1 white (light tan).

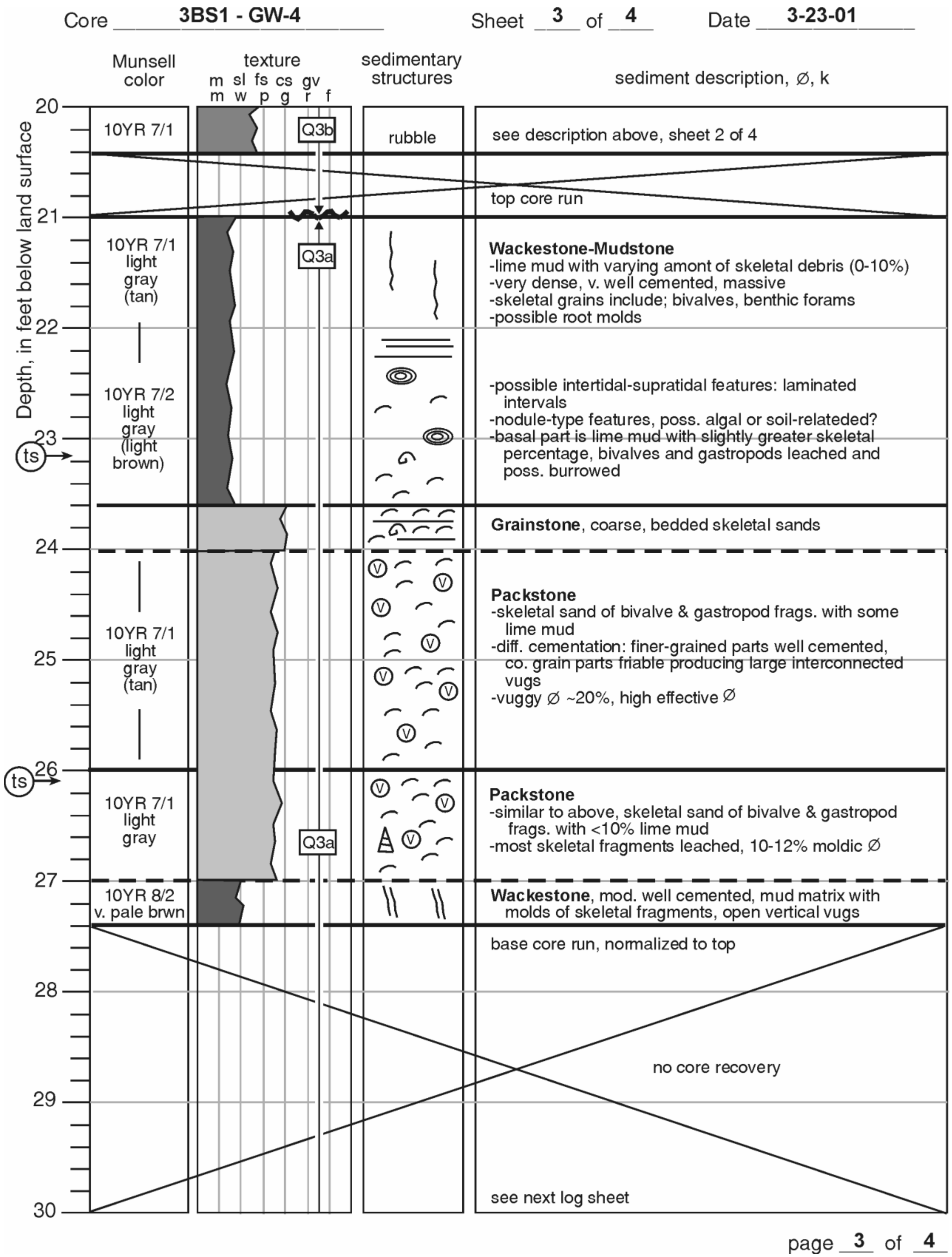
35.00' Bottom of core.


Core 3BS1 - GW-4
Sheet 1 of 4
Date 3-23-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, ∅, k
Depth, in feet below land surface
0
1
2
3
4
5
6
7
8
9
10
peat and organic sediment
8'-9' and 8'-10'
-two bags of rubble containing peloidal rock with bryozoan fragments, pelmoldic ∅ dominant in rock pieces
top rock
2.5Y 7/2 light gray (tan)
Q5
rubble
Packstone-Grainstone
-peloidal and skeletal grains with minor lime mud in matrix
-matrix moderately well cemented
-pelmoldic ∅ and vuggy ∅, high effective ∅
-possible calcrete at bottom of interval
base core run, normalized to top
page 1 of 4

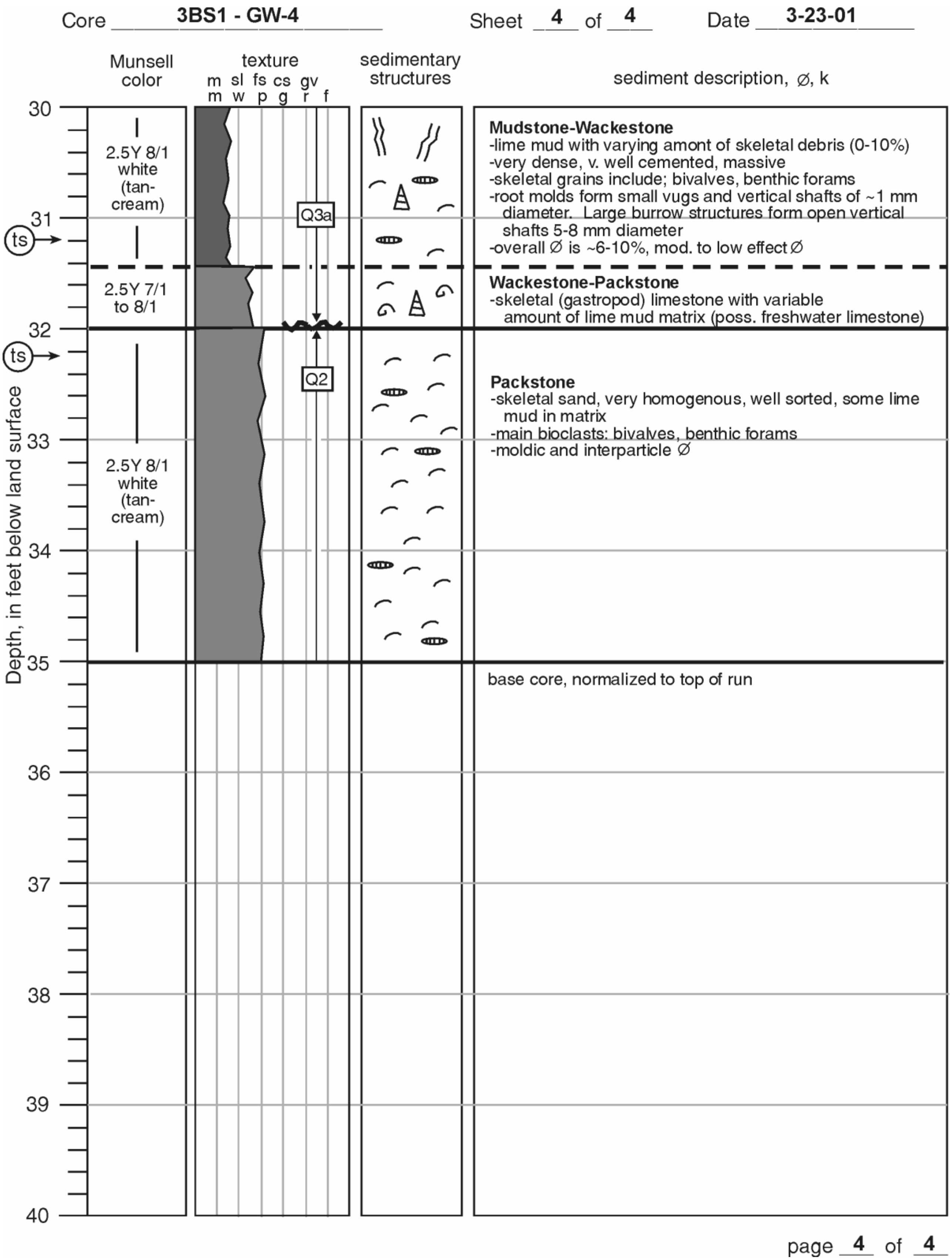
Core 3BS1 - GW-4 Sheet 2 of 4 Date 3-23-01



page 2 of 4



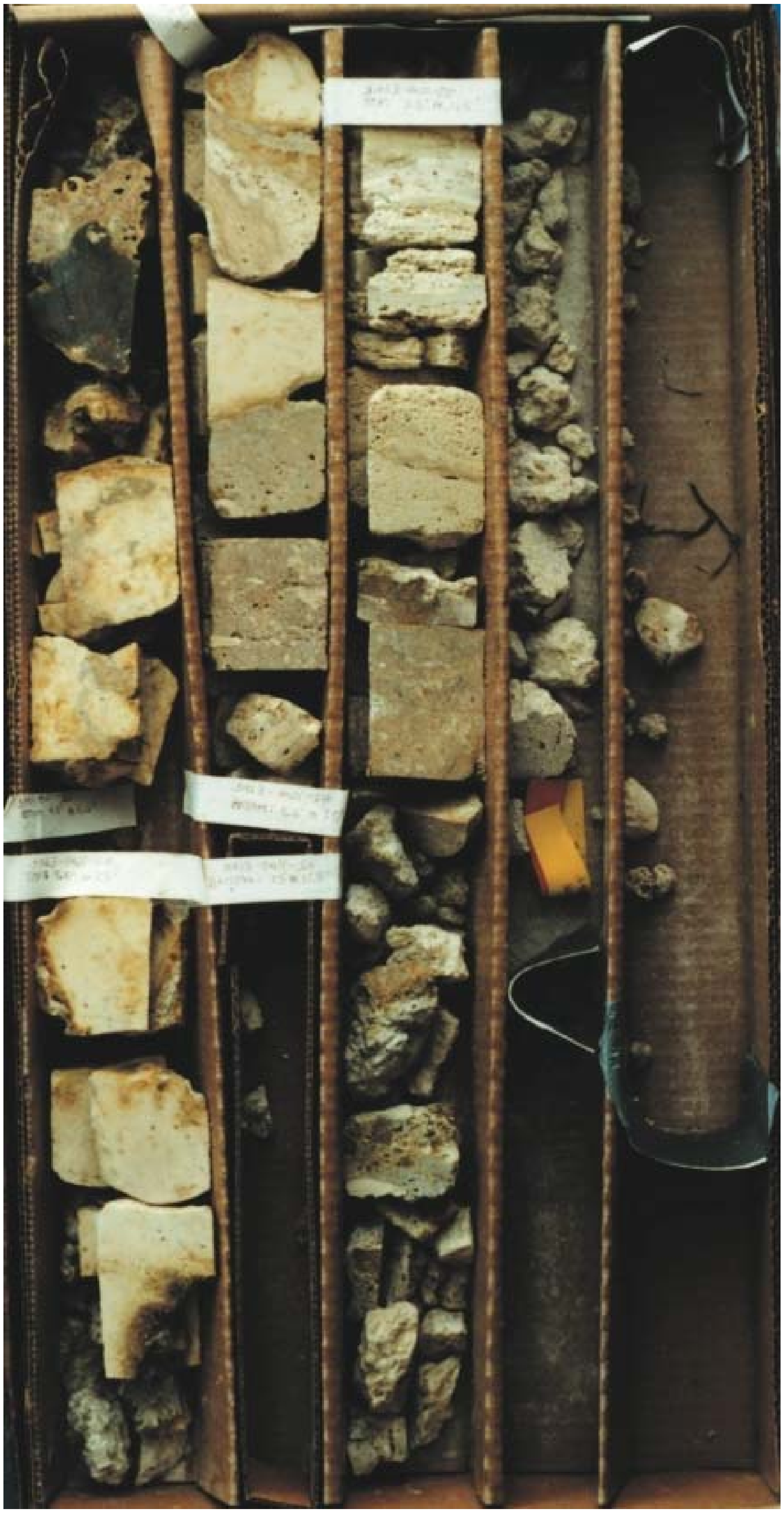
Core 3BS1 - GW-4
Sheet 3 of 4
Date 3-23-01
Munsell color
texture
m m
sl w
fs p
cs g
gv r
f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
20
21
22
23
24
25
26
27
28
29
30
ts
ts
10YR 7/1
Q3b
rubble
see description above, sheet 2 of 4
top core run
10YR 7/1 light gray (tan)
Q3a
Wackestone-Mudstone
-lime mud with varying amont of skeletal debris (0-10%)
-very dense, v. well cemented, massive
-skeletal grains include; bivalves, benthic forams
-possible root molds
10YR 7/2 light gray (light brown)
-possible intertidal-supratidal features: laminated intervals
-nodule-type features, poss. algal or soil-relateded?
-basal part is lime mud with slightly greater skeletal percentage, bivalves and gastropods leached and poss. burrowed
Grainstone, coarse, bedded skeletal sands
10YR 7/1 light gray (tan)
Packstone
-skeletal sand of bivalve & gastropod frags. with some lime mud
-diff. cementation: finer-grained parts well cemented, co. grain parts friable producing large interconnected vugs
-vuggy Ø ~20%, high effective Ø
10YR 7/1 light gray
Q3a
Packstone
-similar to above, skeletal sand of bivalve & gastropod frags. with <10% lime mud
-most skeletal fragments leached, 10-12% moldic Ø
10YR 8/2 v. pale brwn
Wackestone, mod. well cemented, mud matrix with molds of skeletal fragments, open vertical vugs
base core run, normalized to top
no core recovery
see next log sheet
page 3 of 4


Core 3BS1 - GW-4
Sheet 4 of 4
Date 3-23-01
Munsell color
texture
m sl fs cs gv
m w p g r f
sedimentary structures
sediment description, Ø, k
Depth, in feet below land surface
30
31
32
33
34
35
36
37
38
39
40
ts
ts
2.5Y 8/1 white (tan-cream)
2.5Y 7/1 to 8/1
2.5Y 8/1 white (tan-cream)
Q3a
Q2
Mudstone-Wackestone
-lime mud with varying amont of skeletal debris (0-10%)
-very dense, v. well cemented, massive
-skeletal grains include; bivalves, benthic forams
-root molds form small vugs and vertical shafts of ~1 mm diameter. Large burrow structures form open vertical shafts 5-8 mm diameter
-overall Ø is ~6-10%, mod. to low effect Ø
Wackestone-Packstone
-skeletal (gastropod) limestone with variable amount of lime mud matrix (poss. freshwater limestone)
Packstone
-skeletal sand, very homogenous, well sorted, some lime mud in matrix
-main bioclasts: bivalves, benthic forams
-moldic and interparticle Ø
base core, normalized to top of run
page 4 of 4

APPENDIX III

Slabbed Core Photographs

Core 3AS3 GW-1
(4.0 to 11.5 ft below top of peat)



Core 3AS3 GW-1
(11.5 to 14.5 ft below top of peat)

Core 3AS3 GW-2
(5.0 to 12.0 ft below top of peat)

Core 3AS3 GW-3
(5.0 to 12.0 ft below top of peat)

Core 3AS3 GW-4
(3.5 to 14.0 ft below top of peat)

Core 3BS1 GW-1
(5.0 to 18.5 ft below top of peat)

Core 3BS1 GW-1
(18.5 to 33.5 ft below top of peat)

Core 3BS1 GW-2
(5.5 to 19.0 ft below top of peat)

Core 3BS1 GW-2
(19.0 to 29.0 ft below top of peat)

Core 3BS1 GW-3
(5.5 to 21.5 ft below top of peat)

Core 3BS1 GW-3
(21.5 to 28.5 ft below top of peat)

Core 3BS1 GW-4
(8.5 to 12.5 ft below top of peat)

Core 3BS1 GW-4
(12.5 to 24.0 ft below top of peat)

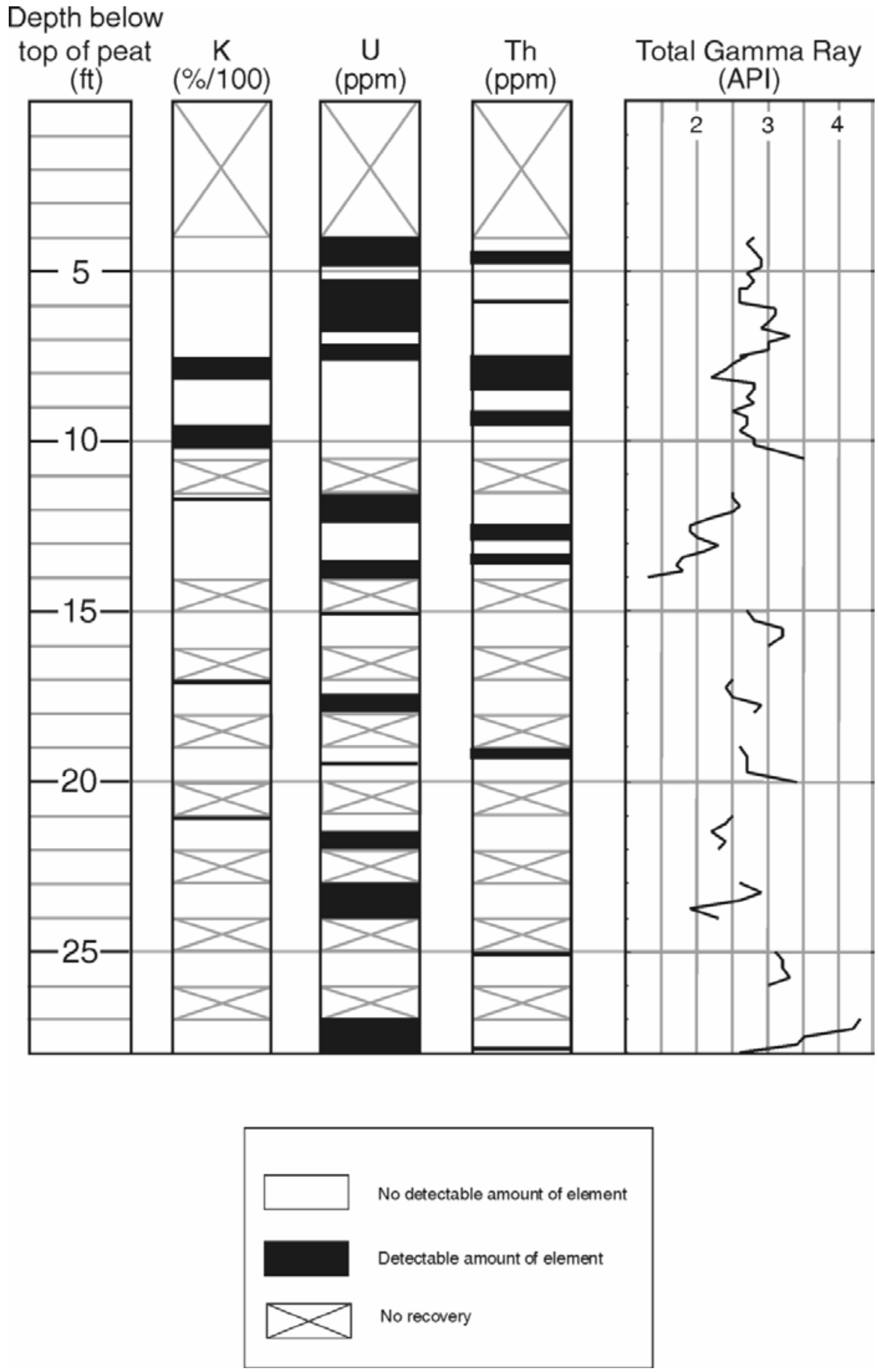
Core 3BS1 GW-4
(24.0 to 34.0 ft below top of peat)

Core 3BS1 GW-4
(24.0 to 34.0 ft below top of peat)

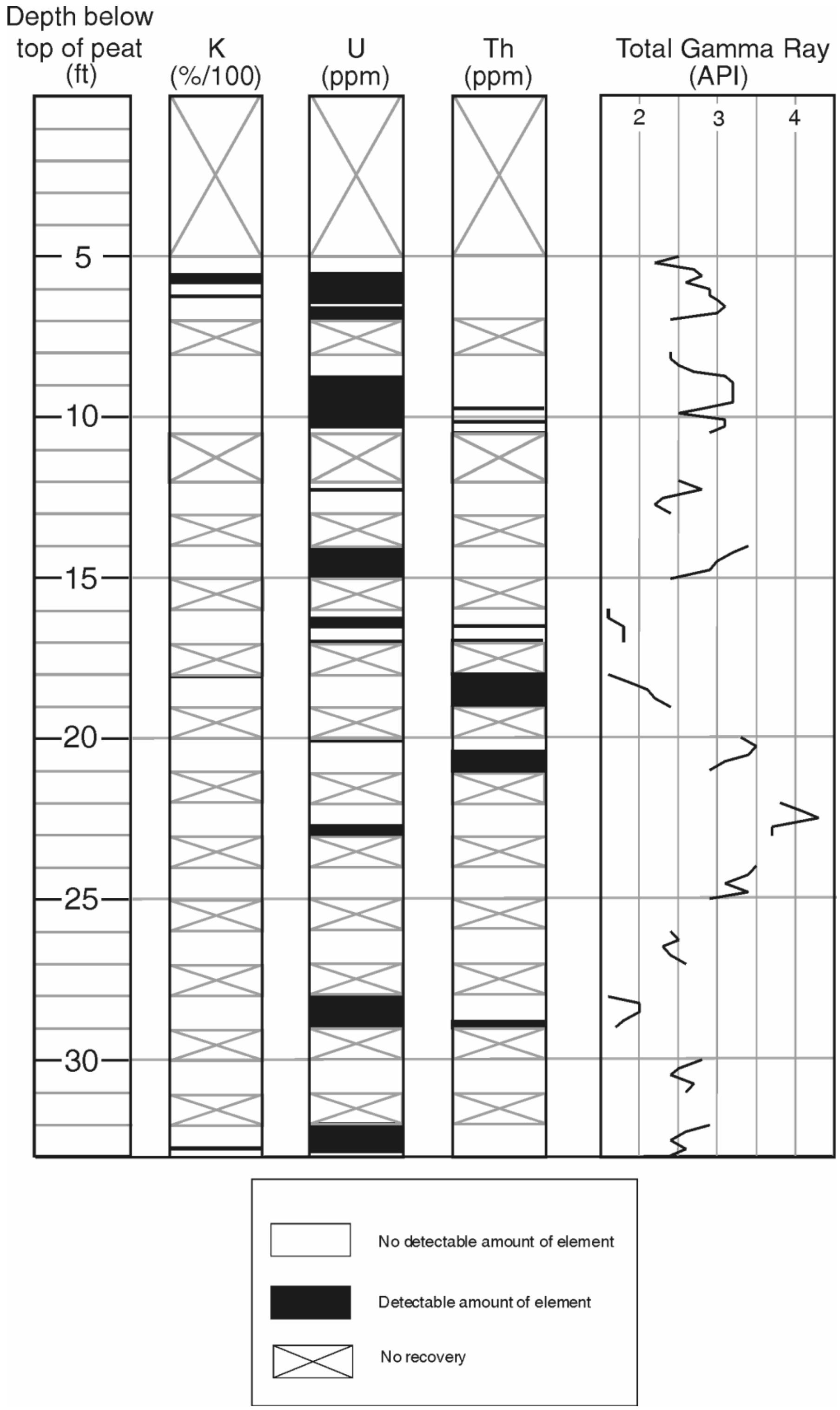
APPENDIX IV

Occurrence of Spectral Gamma-ray Components

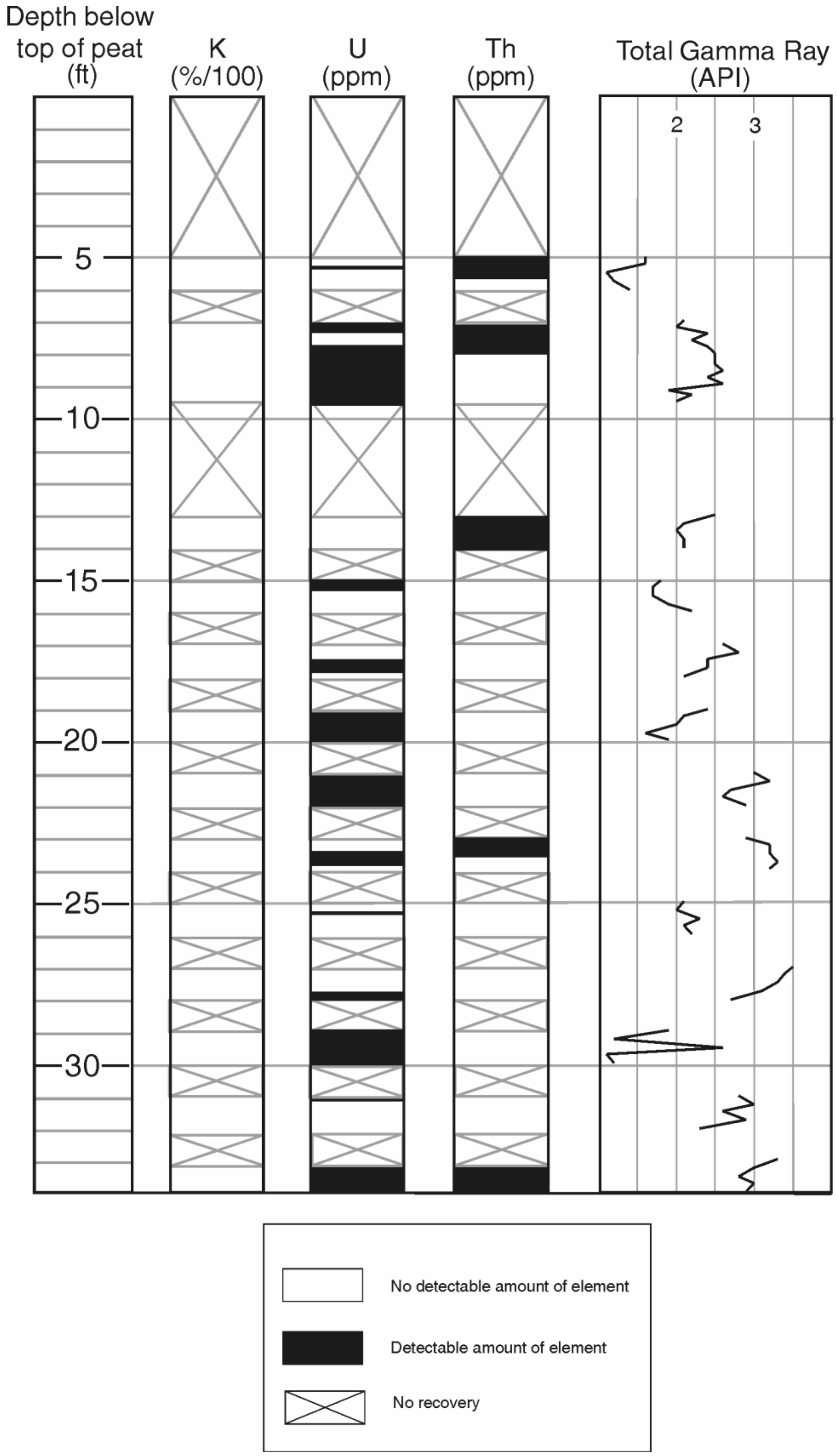
Core 3AS3 - GW1



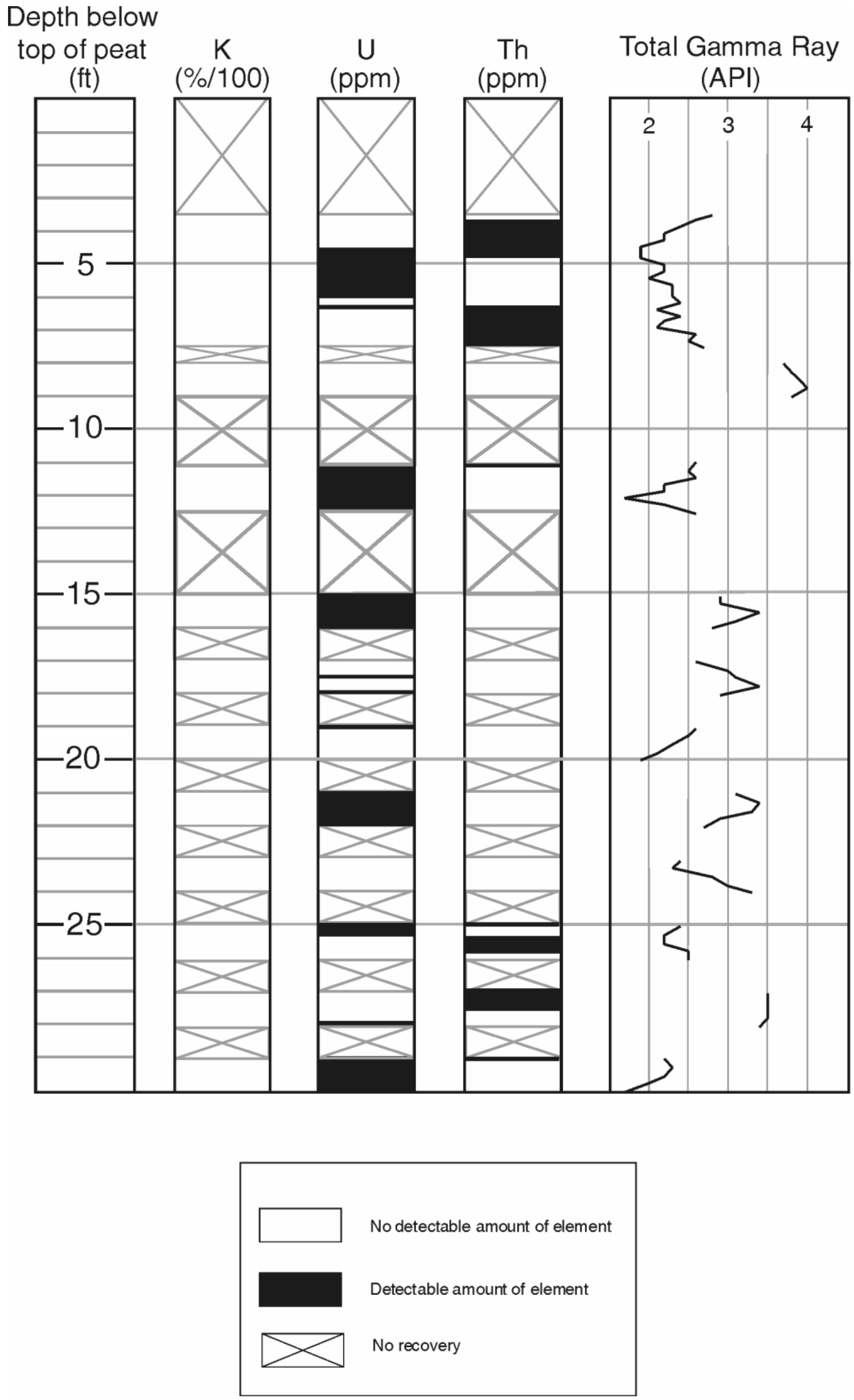
Core 3AS3 – GW2



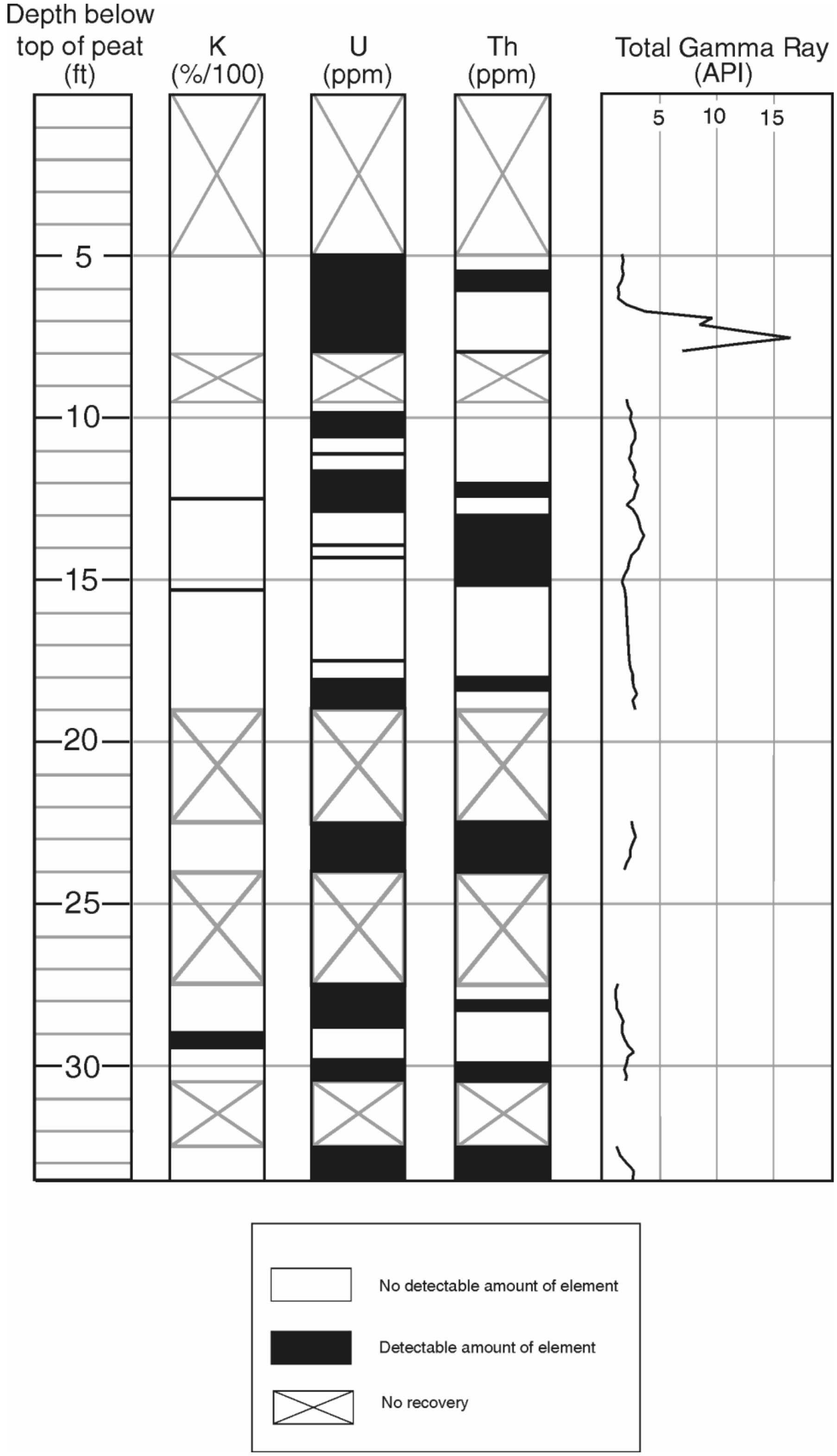
Core 3AS3 – GW3



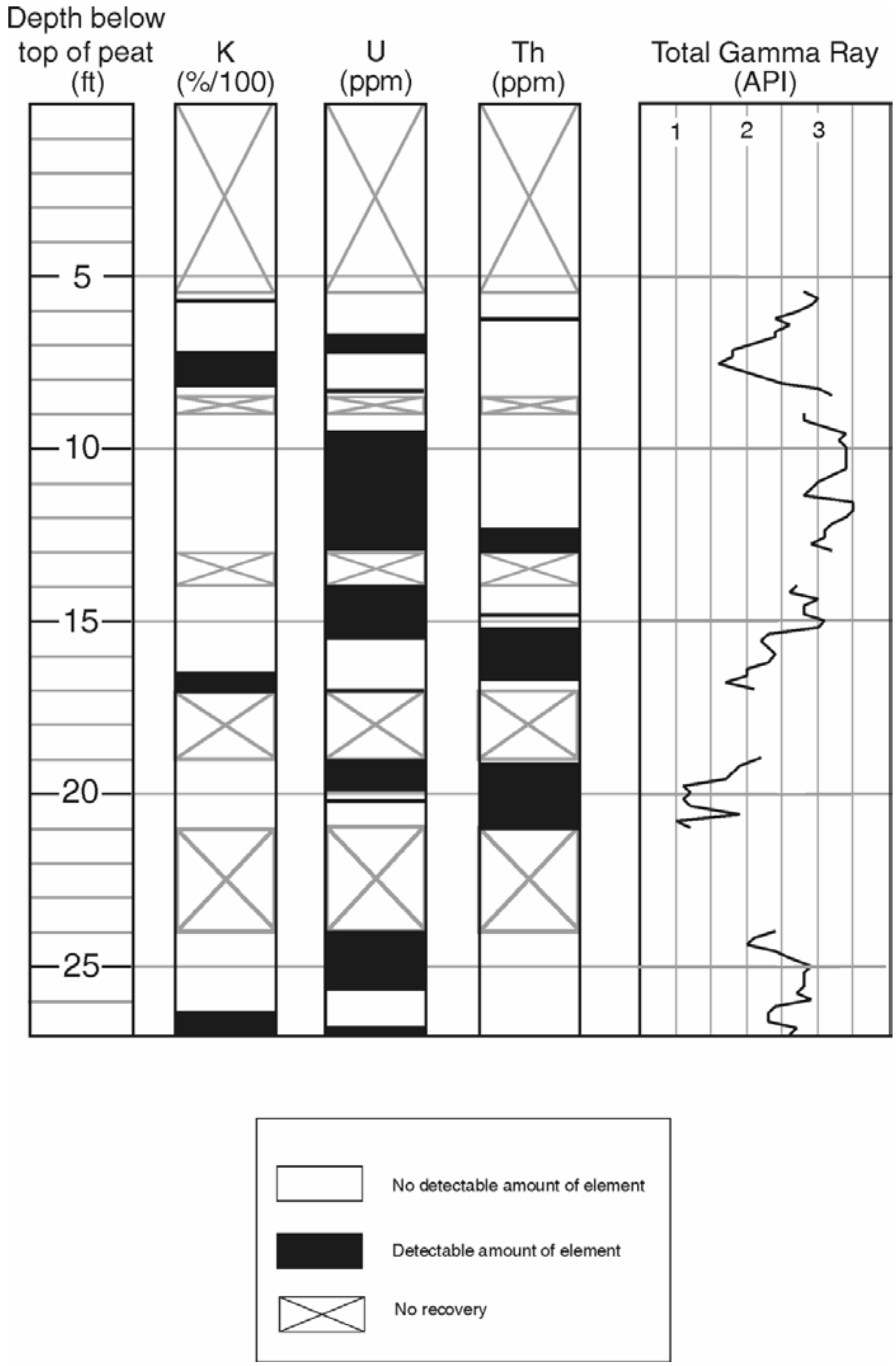
Core 3AS3 – GW4



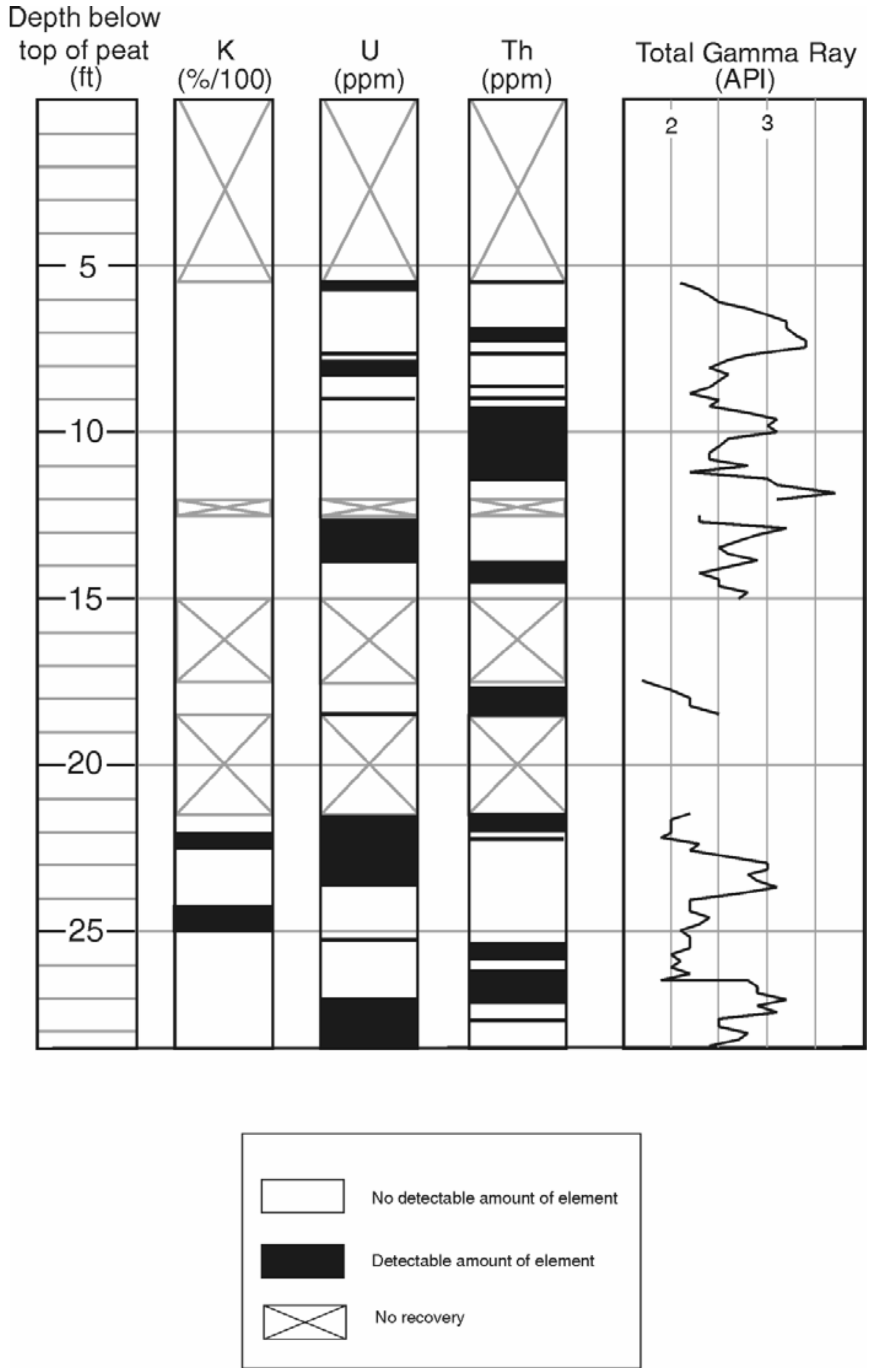
Core 3BS1 - GW1



Core 3BS1 – GW2



Core 3BS1 – GW3



Core 3BS1 – GW4