

Pamphlet to accompany 1:24,000-scale geology mapping, coastal region south of Grays Harbor and east of Willapa Bay

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Overview

Southwestern Washington geology encompasses a broad range of Cenozoic lithologies and a complex structural and tectonic history. Modern estuarine systems are found in Grays Harbor and Willapa Bay, with highlands south of Grays Harbor and east of Willapa Bay. The coastal region adjacent to these modern estuaries was previously mapped as a single unit, with Quaternary sediments at elevations up to 160m a.s.l. Wagner (1967a, b) defined the sediments as undifferentiated terraces deposits (Qt) consisting of “relatively unconsolidated” clay to gravel, and with “ancient bay-fill deposits” at elevations over 100m. Although later mapping differentiated some deposits in the southern part of Willapa Bay (Wells, 1979; Wells, 1981), maps continued to show the region directly south of Grays Harbor and around Willapa Bay as a single unit (Walsh et al., 1987). The region does not have 1:24,000 scale geologic mapping. The 1:250,000-scale map describes the unit as “Silt, sand, and gravel of diverse composition and origins, such as ... uplifted marine and estuarine deposits” (Walsh et al., 1987).

Clifton (1983) provided detailed description of the Quaternary coastal sediments that are well exposed along the modern shoreline on the east side of Willapa Bay between Goose Point and Pickernell Creek. Both subtidal and intertidal sediments comprise the exposures, which suggest a varying depositional environment, much like today’s modern estuary. The deposits show laterally alternating environments, such as estuarine deposits cut by tidal channel deposits (Clifton and Phillips, 1980), and are dated to the Pleistocene based on amino acid racemization ages from bivalve shells (Kvenvolden et al., 1979). Clifton (1983) describes the exposed sediments as marine estuarine deposits that have been uplifted since deposition during past sea-level high stands and notes that higher elevation deposits are likely older terraces, implying a similar depositional setting to the lowest elevation deposits. The Pleistocene estuarine deposits are preserved only at this location on the coast, suggesting the region has long been estuarine. Higher elevation deposits were not described in any detail, mostly due to poor access. The potential for unmapped faults or a record of subduction-related long-term permanent uplift incited this investigation, aided by recent lidar data for the region. This pamphlet describes the geologic and geomorphic characteristics of newly differentiated units as well as field observations portrayed in the accompanying maps and stratigraphic sections. I also describe interpretations of unit origin and relative geologic relationships as based on my field observations and the vast work that precedes me. Field notes and photographs, as well as all figures referred to in this pamphlet, can be found at <http://hdl.handle.net/1773/46938>.

Maps and Plates

Map 1. Quaternary geology, southwestern Washington coast, south of Grays Harbor and near Willapa Bay. ~1:24,000 mapping over 1m and 10m DEM, with nearby 1:100k geology.

Map 2. Quaternary geology with labeled field station locations showing primary lithology, region south of Grays Harbor. ~1:24,000 mapping over 1m DEM, with nearby 1:100k geology.

Map 3. Quaternary geology with labeled field station locations showing primary lithology, Willapa Bay. ~1:24,000 mapping over 1m DEM, with nearby 1:100k geology.

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Plate 1. Measured stratigraphic section for unit Qt1.

Plate 2. Measured stratigraphic section for unit TQss.

Plate 3. Topographic profile with schematic stratigraphic observations at field stations, South Bend area

Plate 4. Topographic profile with schematic stratigraphic observations at field stations, Westport area to North Cove.

Plate 5. Topographic profile with schematic stratigraphic observations at field stations, south of Grays Harbor

Tables

Table 1. Field station numbers with general unit description.

Figures

Figures 1-11 Field photos showing units described in text.

Additional attachments

Field notes, organized by date and field station number.

Field photographs organized by date and field station number.

Appendices

Appendix 1. Geomorphic analysis for terrace identification

Methodology

I used digital elevation models (DEMs) to conduct GIS-based geomorphic analyses as well as base maps for mapping. Both 1m and 10m DEMs are available for the field area. I compared a GIS-based topographic smoothness analysis for a small section of the field area using both 1m and 10m DEM. The results were comparable so for efficiency, I used the 10m DEM for the remainder to of the geomorphic analyses including analyses to determine slope angle, topographic smoothness, and to construct topographic profiles (see Appendix 1). The 1m DEM was obtained from lidar collected and processed by Quantum Spatial in 2019, contracted by the U.S. Geological Survey and the Washington Geological Survey. I used the 1m DEM as a base map for ~1:24,000 geologic mapping (Maps 1-3). The 1:100,000 geologic mapping is shown on the maps outside of the field area (Washington Division of Geology and Earth Resources, 2016)

Observations made at outcrops or in hand-dug pits in the field area support my unit descriptions, geologic maps, and stratigraphic sections. Geologic mapping was conducted during field seasons 2019 and 2020. I described hand samples of sediments in the field, including descriptions of soil profiles where exposures were near ground surface. In most of the gravel deposits the clasts are weathered through or have thick oxidation rinds, rendering lithologic identification difficult. Where gravels were less weathered I conducted point counts of lithology in random locations at an outcrop within a set measured area ranging from 18-48cm wide by 12-36cm high, of all clasts between 4mm-8cm. (e.g. granitic, metamorphic, sedimentary, volcanic, not identifiable). I measured dip and dip-direction of cross-beds where present. For the two units exposed as sea-cliffs I measured stratigraphic relationships with a transit to create simplified stratigraphic sections (Plates 1 and 2). Stratigraphic observations along topographic profiles are schematic, with approximate measurements made at outcrops using measuring tapes (Plates 3-5).

Portions of the field area were not accessible due to locked gates or private property. Where these regions were geomorphically and spatially conformable with nearby field observations they were included within a given unit. Where inaccessible areas lack nearby observation or nearby observations include conflicting unit interpretation they are mapped as “not accessed”. In some instances, terrace 1 (Qt1) is mapped by geomorphic characteristics and direct observations by previous workers.

All field data is organized according to field station name (Table 1). Field notes and field photographs are organized as an attachment by date and field station number.

Unit descriptions in mapped areas

Please note that these unit descriptions are not in age order. For a discussion of age relationships and an interpretation of geologic history of the area, please see Stanton et al, in prep.

Terrace 1 (Qt1)

Geomorphically smooth surfaces, between 13-22m a.s.l. Thinly bedded silts and fine sands with minor clay and massive-to-cross-bedded, fine to medium sands with silt rip-up clasts (Plate 1). Sands are generally quartzo-feldspathic with trace to abundant mica. At many locations between 0.8-2 m above modern beach level is a 0.5-1m-thick bed of broken shells, underlying a bioturbated massive silt-to-sand layer with trace wood fragments and branches (Figure 1). According to Clifton (1982), all beds are cut by channel deposits. Where observed, the channel deposits consist of cross-bedded, medium-to-coarse sand to cobbles, with rip-up clasts of silt and clay. Cross beds are less than 0.25m high. Channel deposits are between several meters to tens of meters wide. Depth to Cox horizon in soils is between 0.5m-0.75m.

Terrace 2 (Qt2)

Geomorphically smooth surface between 35-48m a.s.l. mantled by thinly bedded blue-grey to brown silts and fine sands and massive-to-cross bedded, fine to medium sands (Figure 2). Where terrace is exposed, these deposits are underlain by older estuarine deposits (TQss), although the sands and silts of terrace 2 (Qt2) are also present in stream channels and minor embayments cut into the TQss deposits (see below). Soils are orange to brown, with depth to Cox horizon between 1-2m.

Older estuarine deposits (TQss)

Indurated, stiff, thinly bedded silts and fine sands, and massive-to-cross bedded, fine to medium sands cut by oxidized, cross-bedded medium-to-fine sand to cobbles with silt rip-up clasts (Plate 2; Figure 3). The thinly bedded silts and fine sands show soft sediment deformation (Figure 4) and are occasionally gently tilted, with other layers at angles to the dipping sediment (Figure 5). Geotechnical investigations by the Washington Department of Transportation (1997) near northwestern Willapa Bay at the main Willapa Bay tidal channel include both borings and seismic surveys. These show dense to very dense silts and sands extending several hundred feet offshore to depths up to ~27 m below sea-level. These dense sediments form a bench, with the upper bench surface at ~9m below sea-level. Slightly less dense sands and silts sit stratigraphically above the denser material in some locations. Very loose Holocene sands and gravels form a wedge atop the dense sands and silts, which are interpreted to be Pleistocene “terrace” deposits and correlated to the cliff-forming “terrace” deposits along the northern side of Willapa Bay (DOT, 1997). Addicott (1966, 1974) notes that the compact silts and very fine sands

in the cliff-forming deposits contain fossilized, extinct, bivalves, providing a Pliocene to early-Pleistocene age for the deposits, although later work suggests sediments bearing these bivalves may be as young as mid-Pleistocene (Meyer et al., 1991). Clifton (1982) refers to these as the “older estuarine deposits” and I suggest they are the very dense silts and sands forming offshore benches at northwestern Willapa Bay. Above sea-level these older deposits appear to have been wave cut in some locations, creating the flat and smooth surface between 35-48m a.s.l., while in other locations there are sea-cliff exposures of the indurated estuarine deposits but without a geomorphically distinct surface. While these older deposits do not always form a distinct geomorphic surface, they are not found at elevations over about 60m a.s.l.. Additionally, there appear to be less indurated sands and silts on the higher surface and deposited in valleys incised into that surface that I map as terrace 2 (Qt2). It is possible this unit also underlies unit terrace 1 (Qt1) deposits. Figure 6 shows a possible stratigraphic relationship between units Qt1, Qt2, and TQss.

Chehalis River deposits near Cosmopolis (Qfch)

Indurated, cross-bedded, medium sand to cobble underlying interbedded blue-grey sandy clay to silt. Sandier portions contain minor pumice layers and are cut by coarser sands and gravels. Cobbles are oxidized but not weathered through and with minor or no weathering rind (Figure 7). Includes clasts of granitic and metamorphic lithology. Depth to Cox horizon in soil less than 1m.

Sands near South Bend (Qss)

Thinly bedded, blue-grey to tan silts and clays to bedded to massive, slightly oxidized fine sands with silt lag deposits (Figure 8). Silts and clays occasionally with hard, iron-rich interbeds approximately 1-1.5cm thick. Sands are quartz- and lithic-rich and infrequently with faint cross-bedding. Often sand has manganese oxide (?) coating. Soil has depth to Cox between 1-1.5m. The relationship of these deposits to Qt2 and TQss are not obvious in the field.

Sands between Westport and Tokeland (Qsg)

Cross-bedded fine-medium sand interfingering with coarse sand and gravel and silts at elevations from near sea-level to over 60m a.s.l. forming an abrupt western escarpment north of North Cove between Willapa Bay and Grays Harbor (Figure 9). Cross-bedding height often up to 1-2m, with dip direction west to northwest. These are commonly capped with loose, fine-to-medium, massive to cross-bedded quartz rich sands (Figure 10). Soils has depth to Cox horizon between 0.75 and 1.5m. The cross-bedded deposits resemble descriptions by Clifton and Phillips (1980) of tidal deposits in the Willapa Bay main tidal channel, called North Channel, which is south of these sediments. Side scanning sonar and oriented cores indicate the main tidal channel has irregular- and straight-crested bedforms up to 4m high comprised of sands, gravels, shells, and wood fragments. North Channel experiences intense tidal currents, between 1-1.5m/s, and is known to move laterally through time; present-day shoreline erosion is occurring on the northeast side of the channel, encroaching on Cape Shoalwater and Hwy 105 near North Cove (Washington Department of Transportation, 1997). I suggest the sands and gravels are tidal channel deposits and/or offshore current deposits. The cross-bed height suggests large currents and the capping of clean sand suggests the depositional environment changed from high currents to a beach. The relationship of this unit to other units is not obvious in the field, although along the western side of this unit there are no other units stratigraphically below that can be observed in the field.

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Gravels and sands south of Grays Harbor (Qgs)

Oxidized, cemented, cross-bedded to massive, medium-to-coarse sands to gravels in regionally extensive beds at elevations over 60m a.s.l (Figure 11). Sands are quartz- and lithic-rich with trace to no mica. Cross-bedding ranges from several centimeters high up to approximately 0.75m high, with dip direction generally to the west and southwest. Infrequently, sand and gravel associated with silt and clay beds up to 4m thick. In these cases, there may be rip-up clasts of silt and clay within the cross-bedded coarser sediment. Manganese-and-iron rich weathering rinds of 1mm thick and greater are common on gravels. Sediments are highly weathered with some gravels weathered entirely through. Where not weathered through, gravel lithology includes sedimentary rocks (~17% of clasts) as well as granitic rocks (~14% of clasts), metamorphic rocks (11% of clasts) and volcanic rocks (11% of clasts). Most gravels were too weathered for definite identification (47% of clasts). Soils are orange-red, commonly showing platy to blocky ped structure, mature, with depth to Cox horizon greater than 2m. The relationship of these deposits to other units is not obvious in the field.

River terraces (Qrt)

River terraces geomorphically identified as low-lying platforms above the modern platform (Qal). Field observations show silts, fine-to-medium sands, and occasional gravel.

Quaternary alluvium (Qal)

Modern river deposits, identified in lidar as lowest geomorphic platforms surrounding streams.

Quartzite bearing deposits in southern Willapa Bay (Qfcr)

Silty sands to cobbles, commonly faintly cross-bedded and with clay to silt rip-up clasts. In general, modal percentage of sands consist of 40% feldspar, 10-15% quartz, 10% dark minerals, possibly amphiboles, 2-4% mica, and 31-38% lithic fragments and/or unidentifiable minerals. Where present, cobbles are well rounded, and consist of abundant quartzite and minor granitics. Sands and silts weather to orange-brown. Soils forming on the deposits are generally orange-red and silt rich with minor clay component. Rip-up clasts consist of light tan clay to silt, commonly elongate with orientation parallel to cross-bedding. Geomorphically similar to other terraces in region, so identification hinges on presence of quartzite cobbles.

Bedrock

Oil and gas exploratory well logs from 1940s and 1950s indicate thick deposits of sand and gravel in the higher elevations south of Grays Harbor, with the depth to bedrock ranging from approximately 50m to nearly 450m. The regional sedimentary bedrock consists of siltstone, sandstone, and conglomerate, which are frequently loosely indurated where fresh and weather to very loosely indurated. It is difficult to determine the exact depth to bedrock from descriptions of drill cuttings because notes describing “sand and siltstone” may be referring to loosely indurated bedrock or to compact sediments. Generally, the bedrock surface beneath the Quaternary sediments appears to undulate, possibly representing regional folding. Additionally, the well logs suggest that Quaternary sediments thin to the east.

My field observations indicate some exposures of bedrock in road cuts near the eastern contact in what was previously mapped as Quaternary. These exposures may be more recent than available

for previous studies. I map these as “likely bedrock.” When obvious, I have suggested probable regional units for field stations at bedrock exposures in Table 1 and within my field notes.

Landslides (Qls)

Landslides are abundant in southwestern Washington and there are numerous landslides ranging from several square meters to several square kilometers in area. In some instances, I make note of these landslides in my field notes and photographs, particularly when they involve portions of roads. Only a single landslide appears on my geologic map. This slide appears on the 1:100,000 geologic map and I have included it in roughly the same location. Field observations indicate it includes blocks of sediment that resemble Qgs.

Figures



Figure 1 Outcrop located at field station 19GW814.3 near Bay Center, Washington. Scraping tool is approximately 0.25m long and is sitting on a sandy layer with abundant broken shells. Massive sands are stratigraphically above the shell layer, with silts and very fine sands located stratigraphically below. These are part of unit Qt1. View to the east.



Figure 2 Blue-grey thinly bedded silts and fine sands at field station 20GW0714.7. These are part of unit Qt2. View to the south-southwest.



Figure 3 Thinly bedded, indurated silts and fine sand (bottom) with indurated, weathered and oxidized gravels above (darker layer with some vegetation), capped by sands and silt. Two-meter stick for scale in center bottom of photo. Field station 20GW0708.1, near Bridgeport. I interpret this as unit TQss with unit Qt2 on the geomorphically flat surface. This outcrop is represented in Plate 2. View to the southeast.



Figure 4 Silts and fine sands at field station 19GW815.1 showing soft sediment deformation. Unit TQss. View to the southeast.

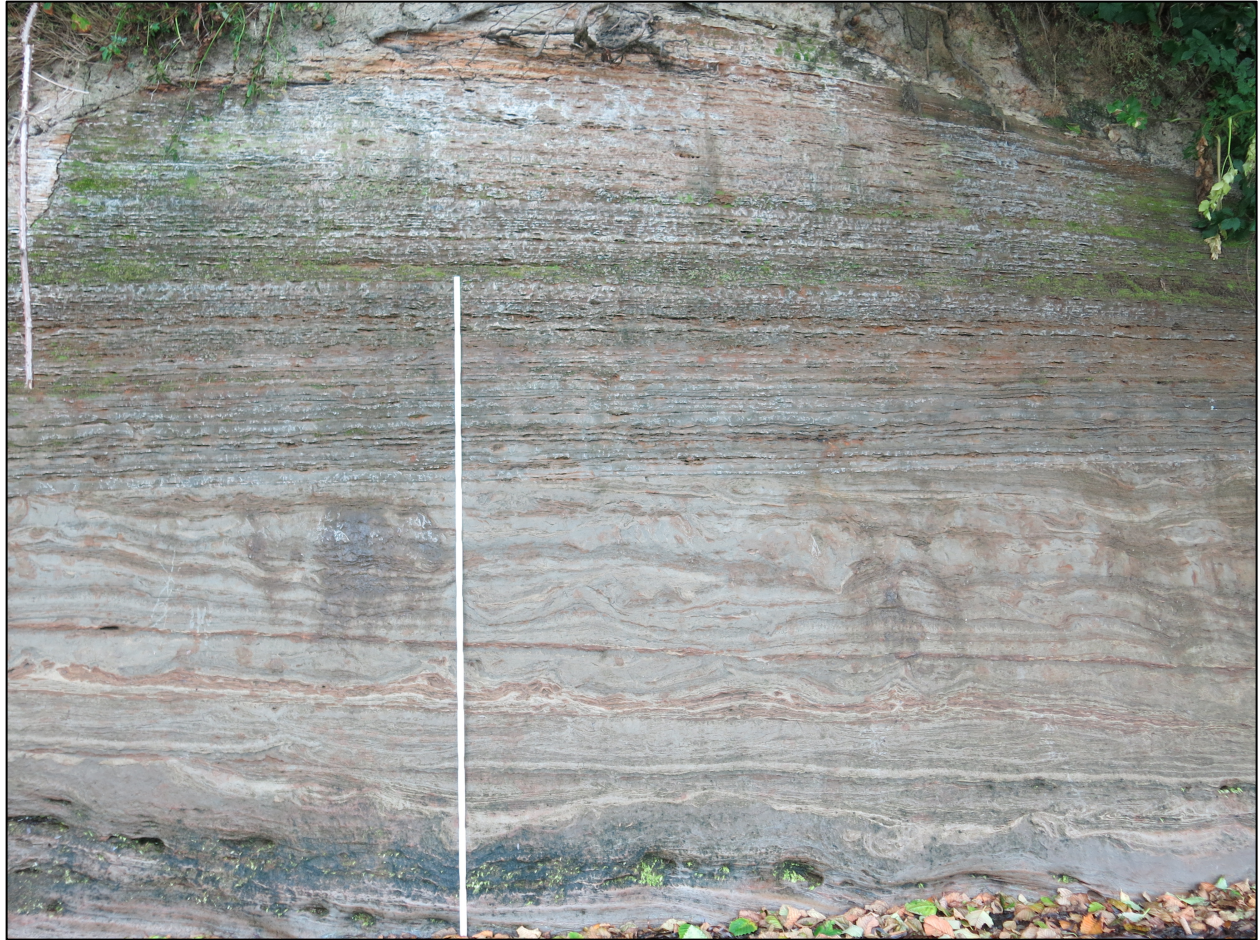


Figure 5. Indurated, thinly bedded silts and fine sands at field station 19GW815.1 showing soft sediment deformation and change in dip angle of beds. Two-meter stick for scale. Unit TQss. View to the southeast.

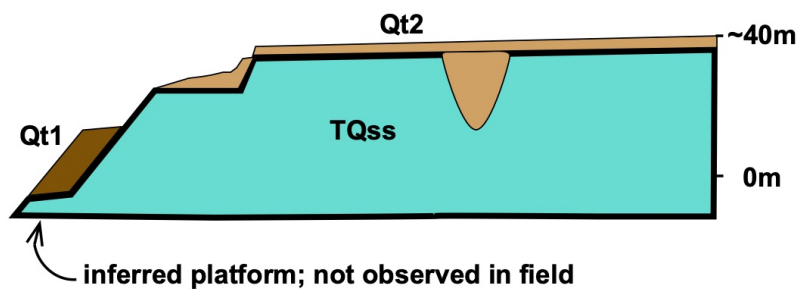


Figure 6 Schematic cross section showing possible relationship between units TQss, Qt1 and Qt2. Sands and silts of Qt2 are found in embayments and mantling geomorphically smooth portions of TQss, which is not terraced at all locations in the field area but not found at elevations above 60m a.s.l. The platform of TQss under Qt1 is not observed in the field but inferred from geotechnical studies near North Cove.



Figure 7 Light grey to tan sand with minor pumice layers (left) cut by oxidized sand to cobble deposit (right) at field station 19GW87.1. Scraper is approximately 25 cm long. Unit Qfch, probable fluvial and tidal deposits related to Chehalis River. View to north.



Figure 8 Subangular to subrounded, fine quartz-rich sand with minor lithics, thinly bedded with minor cross bedding. Oxidized and with minor interbeds of silts. These are field station 19GW89.1 and 20GW0701.1. Unit Qss. View to the east-northeast.



Figure 9 Cross-bedded fine-medium sand interfingering with coarse sand and gravel and silts at elevations from near sea-level to over 60m a.s.l. Field station 20GW0714.6. Portion of wall from top of central talus cone to top surface is approximately 10-12m high, with cross beds up to 1.5, high, dipping generally to the southwest here. Unit Qsg. View to the northeast.

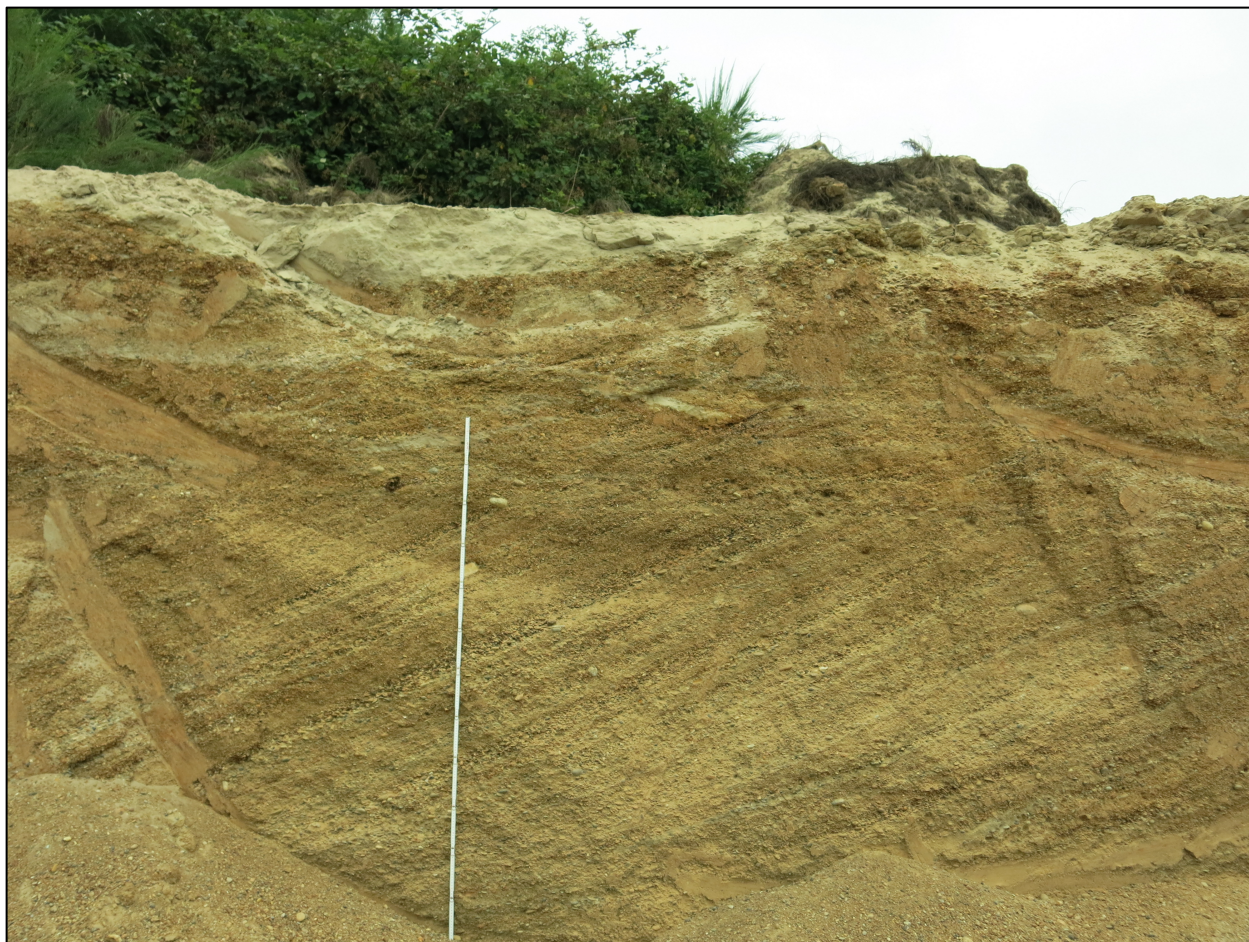


Figure 10 Medium to coarse sands and gravels with crossbedding dipping to the west at field station 19GW88.1. Two-meter stick for scale. Loose, gently cross bedded quartz rich sand capping the coarser deposits. Unit Qsg. View to the north.



Figure 11 Coarse sand to gravel, with cross bedding less than 0.75m high, dipping to west at station 20GW0922.9. Highly indurated and oxidized, with many clasts weathered through. Where identifiable, a portion of clasts are granitic and metamorphic. Unit Qgs. Scraper approximately 25cm long. View to the southwest.

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