Report:
Vibracore of deflation plain sediments and X-ray diffraction of dune soil clays in and around the Oregon Dunes National Recreation Area

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Abstract

X-ray diffraction and vibracore analyses were performed on active and stabilized dunes in and around the Oregon Dunes National Recreation Area. The results of the X-ray diffraction include the detection of vermiculite, gibbsite, and kaolinite. The clay minerals appear to weather in a sequence, from youngest to oldest, vermiculite ⇒ kaolinite ⇒ gibbsite, although this is not entirely supported when considering soil profile development properties. Considering only clay mineralogy, the sequence of core weathering would be HS1, SP1 (sample 261), NW1, and JN1 (sample 3). The vibracoring in the deflation plain revealed that the active dunes directly east of the deflation plain incorporated previous dune sand underling the deflation plain. This indicates that the sand supply to the active dune located behind the deflation plain, was from prehistoric dunes, rather than beach sands. The are and timing of the pre-existing deflation plain dunes have yet to be constrained by thermoluminescent dating.

Methods

Sampling strategy

Soil samples used for X-ray diffraction analysis of clay minerals were selected on the basis of:

1. Amount clay in the profile. There must be an adequate amount of clay in the sample to extract for the analysis.
2. Location. The samples selected could not be clustered in one location.

The sites selected for vibracoring were chosen on the following criteria:

1. Accessibility to roads and pathways wide enough for the vibracore unit,
2. Proximity to previous coring in the study area, and
3. Location in the deflation plain.

X-ray diffraction

The identities of clay minerals in the soil profile are identified from X-ray diffraction on clay sized particles ≤ 2 µm. The summarized methods of deriving the clay sized fraction from the bulk soil sample are as follows, and are fully described in Moore and Reynolds (1997).

1. Soak the sample in distilled water overnight.
2. Sieve the sample to separate out the sand and root material.
3. Apply dispersant (sodium metahexaphosphate) to flocculating slurries.
4. Apply to glass slides from a filter under pressure from a vacuum pump and let air dry. This will produce oriented slides
5. Place under diffractometer and run the sample from 2° to 35° 2θ for 33 minutes. The diffractometer is a Phillips X`Pert x-ray diffractometer recording digital data.
6. Use visual analysis and a computer database to solve for which minerals are present and run additional analysis with glycolated, oven dried, Mg and Na saturated samples to further define samples as needed.

Vibracoring

Vibracoring in the deflation plain of the Florence Dune Sheet (portion of Coos Bay dune sheet north of Umpqua River) took place in late fall/early winter due to the requirement of a high water table. Three cores were taken approximately one kilometer north of the Siltcoos Lagoon (Goose Pasture, OR USGS Topographic map), one immediately behind the foredune, next mid-deflation plain, and at the easternmost boundary of vegetation. UTM coordinates were taken utilizing differential phase correction with a Trimble GeoExplorer II GPS unit. Horizontal datum is NAD27. The GPS base files were downloaded from Portland State University Geology department's base station.

Results

X-ray diffraction

All complete scans are attached as appendix one. The comparison of X-ray diffraction scans of clay minerals in the same soil profile at different depths showed little change in content of different clays (see Figure 1). The peak shifts of width and height did indicate more weathering in the shallower portions of same soil profile. Where the peak width widened and the height lessened, some increased weathering is indicated. In Figure 1, the 10 cm depth shows a more broad 14.31 Å peak with a smaller intensity, therefore more weathering has occurred at the top of the profile rather than near the bottom, as expected.

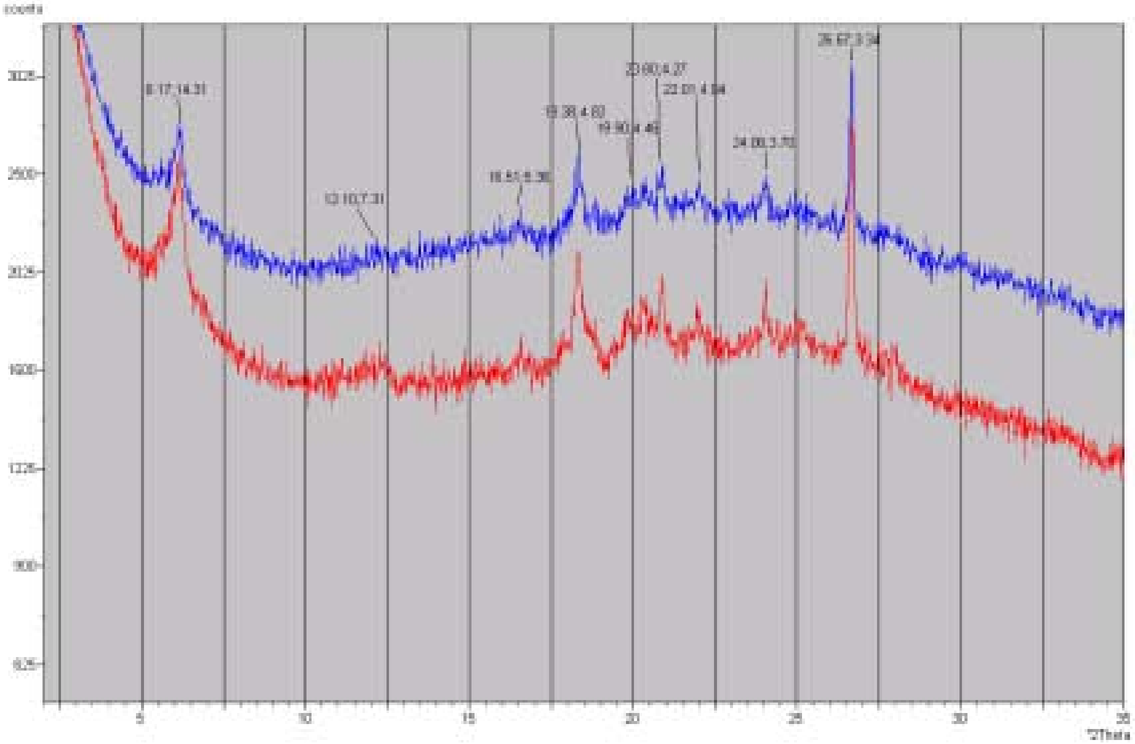

Figure 1: XRD diffraction patterns of NW1. Blue line is at 10cm and red line is at 60 cm depth. Note the relatively small changes in peak intensities. Sample is air-dried.

The clay minerals present in the samples were gibbsite, kaolinite, vermiculite, or a combination of the three. The samples that are older contained a greater quantity of gibbsite, which is the end product of clay weathering sequences. For example, NW1 samples contained the second most gibbsite of the soil profiles, which has a date of stability of approximately 38,000 ybp (Errol Stock, personal communication). At sample site HS1, no gibbsite was present. This site had the least developed soil profile and has an approximate date of stability of 6,000 ybp (Errol Stock, personal communication). At sample location MS1, south of Mercer Lake, as well as other locations, gibbsite has been found in discrete balls in unweathered dune cross-beds (see Figure 2). The morphology of the balls and the cause behind this strange in-situ development is unknown. Sample MS1 was nearly 100% gibbsite, while in profiles such as NW1 (Figure 1), it was much less when comparing profiles. The gibbsite peak of highest intensity in the 4.82 Å peak. Sample 3 also contained large amounts of gibbsite (see Appendix 1).

Table 1: Summary of results of X-ray diffraction.

Sample	Core name	Geographic and UTM Position (NAD27)	Clay minerals present
Sample 3	JN1	4800020 N 396390 E	Gibbsite, vermiculite, kaolinite.
NW1 60cm depth	NW1	Just E-NE of Woahink lake 4864850 N 413990 E	Primarily vermiculite, small amounts of gibbsite and kaolinite.
HS1 30cm depth	HS1	North slough, east of Hauser 4816060 N 402260 E	Primarily vermiculite, small amounts of kaolinite.
Sample 261	SP1	4844150 N 406080 E	Vermiculite with smaller amounts of kaolinite.
MS1 White globules	MS1	On the south east banks of Mercer Lake 4872550 N 413090 E	Gibbsite, with one unidentified peak.

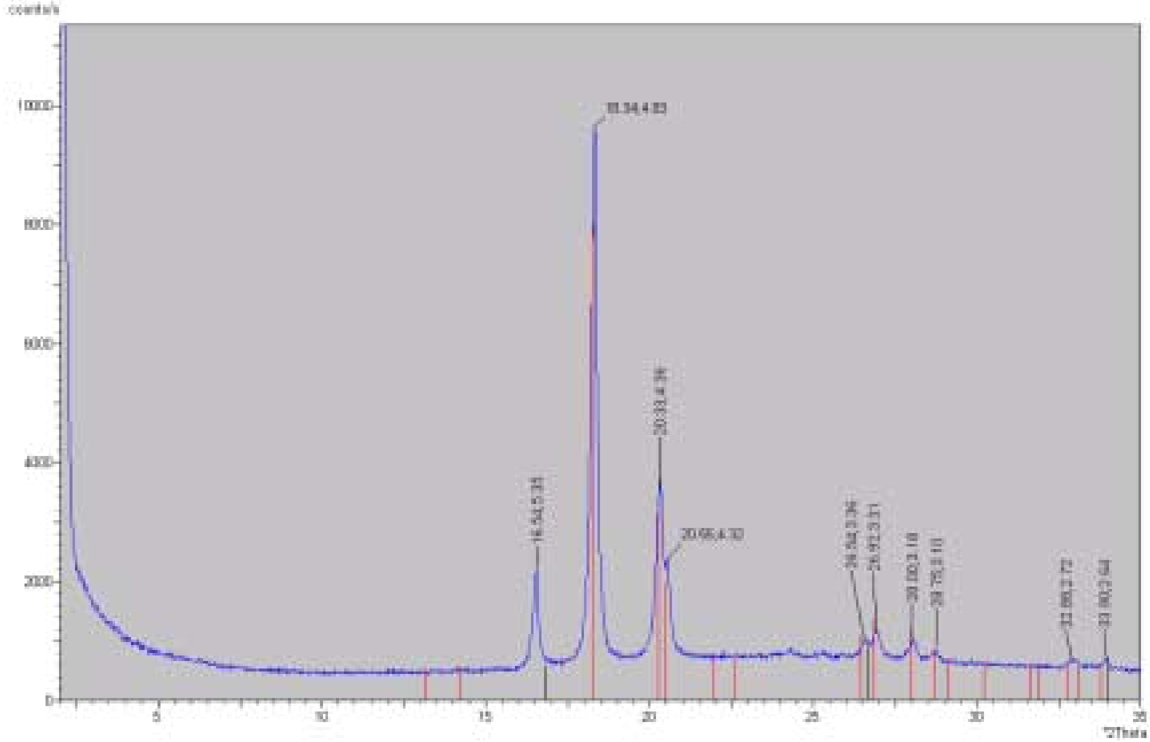

Figure 2: Scan of gibbsite balls from Mercer Lake cross-beds. The red lines are the search-match database results for gibbsite. The 5.35 Å peak is unknown.

A visual qualitative analysis of the XRD scans based on the weathering order of, from youngest to oldest, vermiculite, kaolinite, and gibbsite, was performed. Excluding sample MS1 (the gibbsite 'balls') the order from youngest to oldest would be HS1, SP1 (sample 261), NW1, and JN1 (sample 3). The reliability of this approach is uncertain, due to possible differing sources of the parent minerals. Furthermore, the most weathered profile was NW1, not JN1, as would be expected based on the XRD results and the assumption of the vermiculite ⇒ kaolinite ⇒ gibbsite-weathering model. The soil thickness and color both point the NW1 being the most weathered, and thus the greatest duration of soil profile development.

It is possible that the gibbsite represents weathering of tephra deposits. The gibbsite balls of MS1 would have been aolian pumice fragments blown into cross-beds and fully weathered to gibbsite. Taylor and Lasaga (1997) state that gibbsite weathers from volcanic glass and plagioclase by precipitation and re-dissolution. Also, gibbsite in inceptisols are possible from the weathering of volcanic ash. The other possible explanation is the aforementioned idea of gibbsite being the end product of a weathering sequence of clay minerals precipitated in the sequence vermiculite ⇒ kaolinite ⇒ gibbsite.

Vibracoring

The vibracore sub-surface sampling of the deflation plane revealed that the deflation plane rests on dune sands. There were multiple foresets displayed in the cores. All but one of the cores had nearly the identical grain size in the top as the bottom, and all with the same apparent mineralogy from top to bottom. See Table 2 for a summary of the vibracore results. Figure 3 displays photos of the vibracore sites. Appendices 2 and 3 has the grain size separations and the core logs.

Table 2: Summary of vibracore results.

Core	**Geographic position**	**Northing (m)**	**Easting (m)**	**Mean grain size top (mm)**	**Mean grain size bottom (mm)**
SD1	Immediately behind foredune	4862442	407327	0.1223	0.1472
SD2	At the eastern edge of vegetated deflation plain	4861097	408360	0.1246	0.1220
SD3	At the mid-section of the deflation plane	4863749	408510	0.1189	0.1251
GP1	Near the front of the deflation plane	4867450[*]	408650	0.1335	0.2493
GP2	Neat the rear of the deflation plane	4867450	408650	0.1225	0.1232

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[*] UTM positions from cores GP1 and GP2 were found from a USGS topographic map, rather than using the GPS system.

Figure 3: Photos of vibracore sites. Clockwise from top right: SD1, SD2, and SD3

Conclusions

The soil development of the dunes as classified by the clay minerals could be indicated by the relative amounts of vermiculite, kaolinite, and gibbsite. Although the entire mechanism by which this could be taking place is not known, it does seem to be a viable hypothesis. The precursor mineral of this sequence could be chlorite from off the continental shelf. The chlorite would weather to vermiculite. Karlin (1980) shows the highest levels of chlorite is concentrated to the south of Cape Arago, then trailing off the shoreline at approximately N40°W. If this data are correct, then the source of the chlorite is likely from the south of Coos Bay, blown in by the strong paleowinds directly off the continental shelf. This is supported by ongoing research of paleowind movement. Mix (personal communication, 1998) reports preliminary January paleowind (~40,000 ybp) vectors as N33°E. In addition to the direction, the winter winds are three times stronger then than they are now. The wind vectors would be following nearly in a parallel path as the chlorite trail, increasing the chance and concentration of eolian chlorite being blown off the shelf during a sea level low stand.

Chlorite vermiculitization

The hydroxyl-interlayered vermiculites have been recognized to be an chlorite weathering product (Douglas, 1977; Grim, 1962; Calle and Susquet, 1988; Moore and Reynolds, 1997). Ross and Kodama (1974) suggest that there is likely two stages in the chlorite-vermiculite transition, one of which is applicable to the dune (the other being part of metamorphism). It is acidic weathering giving rise to the transition. They state that the chlorite's hydroxide sheet must first be structurally disordered for the vermiculitization to occur. In pedogenic weathering, the oxidization of ferrous iron likely plays a major role in the initiation of structural disorder. The oxidized iron is required for the selective removal of the hydroxide sheet. The pH of the modern soil profiles in the dunes are sometimes quite low in the A horizon, often in the low fours, with iron pans also occurring (unpublished data)

In this literature search, rates of vermiculitization were not found. However, there are examples of known depositional times of chlorite and subsequent amount of vermiculitization. Argast (1991) detailed the vermiculitization of three meters of chlorite in an aeolian periglacial sand dune in Indiana that had been deposited about 13,000 ybp. In this study, there was involvement of a chlorite/vermiculite intermediary phase. The ferrous iron is oxidized and is subsequently retained in the sediment as goethite and as crystalline and noncrystalline grain coatings. The vermiculite from depths shallower than 64cm is partially expandable and is completely collapsed by K-saturation or heat-treating. The hydroxy-Al vermiculite that is present is typical of the intense weathering under the acidic conditions that are prevalent at the dune surface. In addition, high-Fe chlorites can alter rapidly to discrete vermiculite without forming interstratified chlorite/vermiculite intermediaries. While we found no goethite, there is the possibility that a related process is occurring in the ODNRA.

In conclusion, the weathering products observed in the ODNRA dune soils reflect extreme alteration by acidic meteoric waters leaching very porous sand. This extreme weathering accounts for the thick soil profiles in relatively young (<40,000 ybp) dune deposits.

The results of the vibracoring demonstrate that the current deflation plain is laid upon relict dune sands, rather than on beach. This implies that the active dunes are supplied from active deflation of preexisting dune sand, rather than the modern beach and foredune. The small differences in grain size from top to bottom signify relatively identical environments of deposition. The occurrence of only dunal cross beds and lack of any other distinguishable bed forms implies that the only environment of deposition was a dunal environment.

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Appendix 1: Complete X-ray diffraction patterns.

Appendix 2: Grain size statistics and analyses.

Appendix 3: Core logs

(Photos available upon request)