Mining minerals from sand

Learning objectives

By completing this activity, you will:

- Use ilmenite (a mineral which contains the element titanium), which is mined by DuPont to use as a white pigment, as an example of a mineral resource formed by sedimentary processes.
- Summarize the processes that act to make clastic sedimentary rocks.
- Diagram how sedimentary processes link together to form placer deposits (the heavy mineral sands).
- Explain how the sedimentary processes of mechanical weathering, erosion, and deposition, redistribute and concentrate mineral resources.
- Analyze graphs to interpret erosion and deposition processes that create heavy mineral sand deposits.
- Apply knowledge of sedimentary environment and processes to infer potential types and locations of heavy mineral sand.
- Explain how climate influences chemical weathering and how chemical weathering concentrates certain mineral resources.

Brief background

Figure 1. Map showing the location of the Trail Ridge heavy mineral sand deposit in Florida. The southern portion of the deposit is being actively mined by the DuPont Corporation. Map created using Google Maps; deposit located with Google Earth imagery and sketch map in Force, 1991.

Layers of dark sand, rich in heavy minerals, can be mined for the heavy minerals they contain. For example, the DuPont Corporation mines heavy mineral sand from the Trail Ridge sand deposit in northern Florida. The mineral ilmenite is used as a source of titanium dioxide (TiO_2), which is used to make white plastic and paints more opaque. Other minerals, like zircon and staurolite, are mined to be used as abrasives (to use in sandblasting and to etch tombstones, for example).

The right combination of factors existed in central Florida to make these heavy mineral sand deposits, and incorporate aspects of the geosphere, hydrosphere, and atmosphere. By studying these processes, geoscientists can predict other places that might have heavy mineral deposits, and thus guide exploration.

Part 1. How the sand at the Trail Ridge deposit came to be

> Quartz is found in many rocks, but some of the heavy minerals like sillimanite and kyanite only form in metamorphic rocks that make up the cores of mountains. These rocks broke apart into sand. The sand was carried to the ocean by streams and deposited. Waves picked up the sand from offshore and deposited it on the beach. Winds picked up some of the sand and deposited it in dunes behind the beach.

1. In the description of how the sand deposit formed, circle examples of weathering.
2. In the description of how the sand deposit formed, draw rectangles around examples of erosion.
3. Draw a diagram of how the sand deposit formed.

4. Although its exact age is not known, the Trail Ridge deposit formed in the Pliocene or Pleistocene (sometime between 12 thousand and 5.33 million years ago). Based on today's location of the Trail Ridge deposit, what happened to sea level between the time this sand was deposited and today. Explain how you came up with your answer.

Part 2. Characteristics of the heavy mineral sands, and how sedimentary processes led to their formation

Heavy minerals	**Formula**	**Specific gravity**
ilmenite	$FeTiO_3$	4.7–4.79
zircon	$ZrSiO_4$	4.6–4.7
staurolite	$(Fe,Mg)_2(Al,Fe)_9O_6(SiO_4)_4(O,OH)_2$	3.74–3.83
sillimanite	Al_2SiO_5	3.23–3.27
kyanite	Al_2SiO_5	3.53–3.65
Other minerals	**Formula**	**Specific gravity**
quartz	SiO_2	2.65

Table 1. Some minerals found in the Trail Ridge sands. Recall, specific gravity is a mineral property akin to density. Except for quartz, all the minerals listed are considered "heavy minerals."

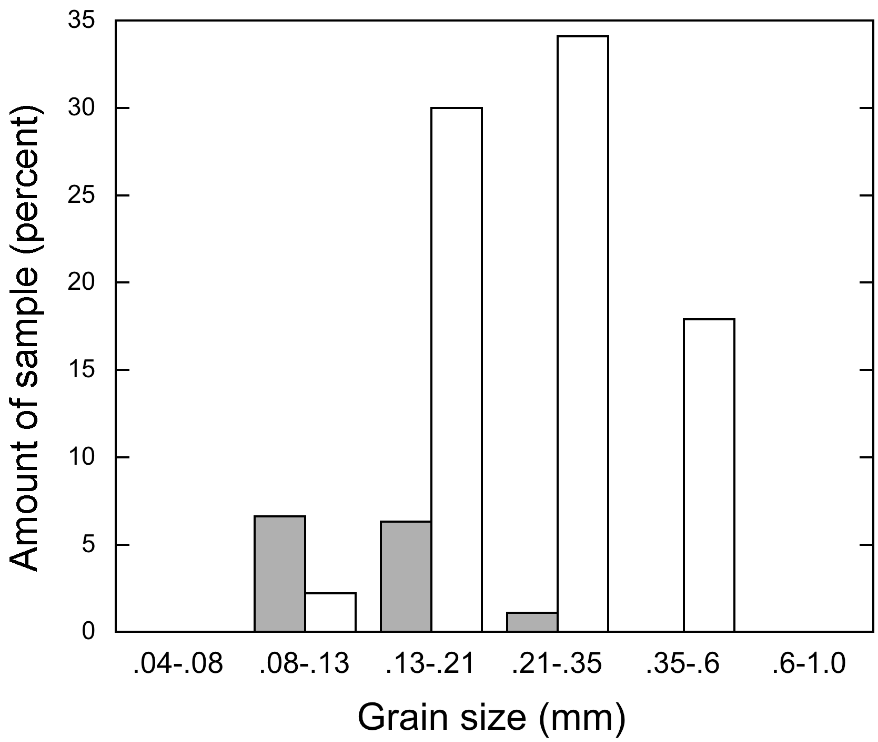

Figure 2. The graph shows size of heavy mineral sand grains (gray bars) and normal quartz sand grains (white bars) from the Trail Ridge deposit (after Force and Rich, 1989).

5. Describe the Trail Ridge sand deposit as shown in the graph.

6. Explain why the sand deposit has the characteristics that it does. Your answer should specifically explain how erosion and deposition has sorted the sand (sorting means the grains are separated by weight, so that particles that weigh the same are deposited together).

7. Draw a graph similar to the one shown in Figure 2, showing the characteristics of a similar deposit formed on the beach instead of a sand dune. Think about how waves might erode and deposit differently than the wind, or, think about what might be left on the beach after the wind eroded sand from there.

8. Do you think the beach deposit would contain more or less heavy minerals? (Would it be more or less desirable to mine the beach deposit?)

Part 3. Concentration of titanium in the mineral ilmenite

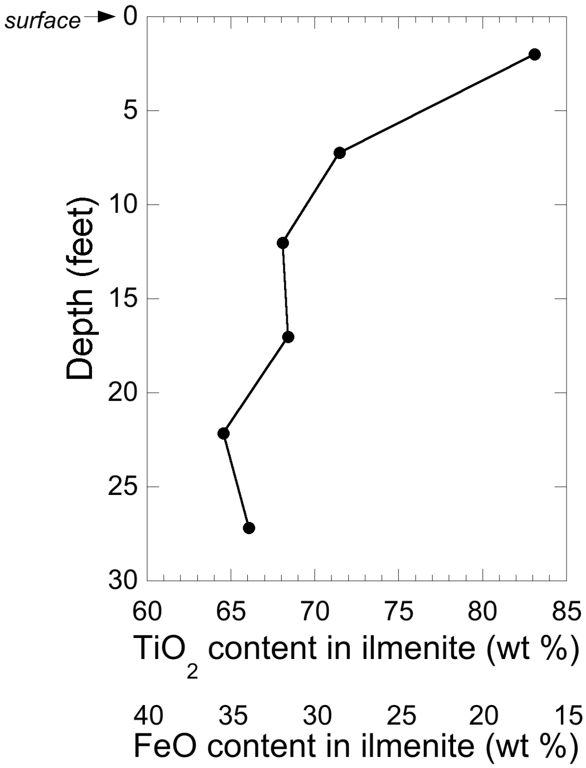

Figure 3. The Trail Ridge sand deposit consists of different layers of sand, which contains ilmenite and other minerals listed in Table 1. The composition of the ilmentite changes with depth (sand analyzed at the surface has a different composition than sand found deeper), and this is shown in the graph. Ilmenite has an average composition of $FeTiO_3$ but the relative amounts of iron (Fe) and titanium (Ti) can vary. "Wt %" means *weight percent*, the weight of TiO_2 in a given weight of the mineral. Two equivalent labels for the x-axis are given, one showing the amount of titanium (Ti) and one showing iron (Fe). So, ilmenite with 83 weight % TiO_2 means that 83% of that ilmenite's mass is TiO_2 , and 17% of the mass is FeO. After Force, 1991.

9. Describe how the composition of the ilmenite changes with depth.

10. What process do you think caused the ilmenite to change?

11. Explain why the ilmenite composition changes with depth, and specifically why this is expected in Florida.

Part 4. Summary

12. What do you think might be the advantage of mining sand as opposed to mining Ti-bearing minerals from metamorphic or igneous rocks?

13. The heavy mineral sand is a mix of minerals (see Table 1). In general, how do you think the mine processing (beneficiation) plant could separate the ilmenite from the other minerals?

14. Imagine that you work for an exploration company hired by DuPont to find new deposits of heavy mineral sands. Describe the type of place you would choose to explore. (Your answer should include the ideal characteristics of a place in which these sands would form.)

References

Force, Eric R. 1991. "Geology of Titanium-Mineral Deposits." GSA Special Paper 259.

Force, Eric R., and Rich, Fredrick J. 1989. "Geologic Evolution of Trail Ridge Eolian Heavy-Mineral Sand and Underlying Peat, Northern Florida." U. S. Geological Survey Professional Paper 1499.