Surface Morphology of Fly and Bottom Ash as Seen with the Scanning Electron Microscope

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Introduction

While studying the gound water flow system underlying a fly ash landfill site near Dunkirk, New York, it became apparent that because particle size and shape play an important role in the determination of porosity, permeability, and other ground water flow characteristics, the study should include a characterization of the physical appearance of both fly and bottom ash. In addition, the identification of these materials is essential in determining the amount of fly and bottom ash within the nearby stream and Lake Erie sediments. This initial morphological description was carried out with the use of the scanning electron microscope (SEM). This report describes our findings to date of cenospheres (hollow spheres), plerospheres (filled spheres), omphalospheres (bellybutton spheres; omphalos, from Greek for bellybutton), glass, scoriaceous material (full of vesicles or small bubbles), and crystalline overgrowths.

The fly ash consisted of two samples: 1) new fly ash collected in May 1976 from a dump truck which had just been filled from the electrostatic precipitator hopper at the Niagara Mohawk Power Company at Dunkirk, New York and, 2) old fly ash collected from the Fredonia Airpark, Fredonia, New York in late May of 1975. The airfield was constructed in 1966; thus, the airpark fly ash was nine years old at the time of collection. The bottom ash examined was all new bottom ash collected in May of 1976.

Results

Micrograph 1 shows typical fly ash morphology; it tends to form into many very smooth surfaced spheres (cenospheres) of different sizes. Also, note the scoriaceous (spongelike) material in the center of the micrograph. Although this material is more common in bottom ash, it is also found in abundance within the fly ash as well. Note that nearly all the vesicles and bubbles within the scoriaceous material are filled with small cenospheres (micrograph 2). Micrographs 1 and 2 are new fly ash samples. Even though the older fly ash has been in the environment nine years, its surface textures and morphology are little changed from that shown in micrographs 1 and 2. Perhaps the only notable difference is that apparently some of the cenospheres are missing or not as abundant in the vesicles of the scoriaceous material of the fly ash (micrograph 3).

Micrograph 4 (new ash) shows a closeup view of the center of micrograph 1. Note that the scoriaceous material is coated with cenospheres. And, the surfaces of these cenospheres are in turn coated with smaller adhering spheres. Higher magnification shows that these small adhering spheres have even smaller adhering spheres on their surfaces. However, the higher magnification does not allow reproducable micrographs to be made and thus they are not shown here.

It has been reported in the literature that crystalline overgrowths on new fly ash are quite common and apparently form gradually as the spheres cool after development (1). In examining several hundred samples of both old and new fly ash, no crystalline overgrowths were found. This apparent discrepancy may indicate that crystalline overgrowths are a function of coal source rather than being common to all fly ash.

According to Fisher et al (2), the occurrence of certain fly ash morphologies is indicative of the sulphur content of the coal burned. The most indicative of these morphologies is the occurrence of plerospheres in the ash content of high sulphur coal. Since the coal burned at Niagara Mohawk Power Company's Dunkirk plant is eastern high sulphur coal and plerospheres were found within the ash, this study supports their conclusions (micrograph 5). In addition, as another possible indicator of high sulphur coal this study has noted characteristic surface indentations on the surfaces of a large number of cenospheres (micrographs 6 and 7). These surface indentations have the appearance of a navel and thus we named spheres having this indentation omphalospheres from the Greek "omphalos" for bellybutton. A careful search of the literature has failed to yield a description of this feature. Since most of the literature we reviewed deals with low sulphur coal and we dealt

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MICROGRAPH 1: *This micrograph shows typical fly ash morphology. There are many smooth shaped cenospheres of different sizes and the scoria mass in the center of the micrograph has its vesicles filled with cenospheres. The width of the field of view is 220 micrometers.*

MICROGRAPH 2: *This micrograph shows a closeup view of a fly ash scoria block. It should be noted that the vesicles are completely filled with cenospheres. The width of the field of view is 22 micrometers.*

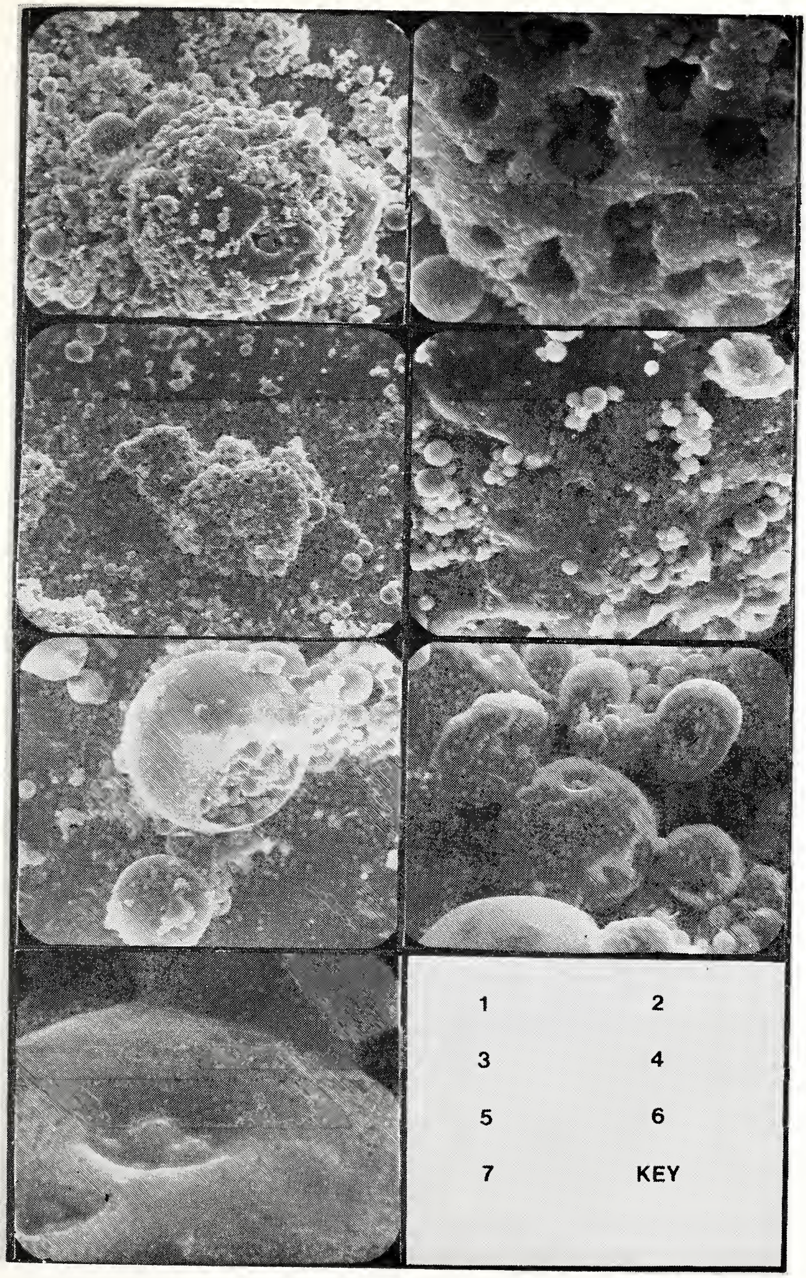
MICROGRAPH 3: *This micrograph shows the morphology of some of the older fly ash. Note that there is little difference in the morphologies displayed among micrographs 1, 2, and 3. The width of the field of view is 220 micrometers.*

MICROGRAPH 4: *This micrograph is a closeup view of the center of micrograph 1. Note that the scoriaceous material is coated with cenospheres and that the cenospheres have even smaller cenospheres attached to their surfaces. The width of the field of view is 55 micrometers.*

MICROGRAPH 5: *Micrograph 5 shows a good example of a plerosphere. Note that the large sphere near the top center of the micrograph is filled with smaller cenospheres. If these smaller spheres are in turn broken open, they would be seen to also be filled with spheres. The width of the field of view is 110 micrometers.*

MICROGRAPH 6: *This micrograph shows several cenospheres which have one or several indentations on their surfaces. We have named these omphalospheres and believe they are indicators of a high sulphur coal source. The width of the field of view is 55 micrometers.*

MICROGRAPH 7: *This micrograph is a closeup view of the omphalosphere in the center of micrograph 6. It shows detail of the surface indentation. The width of the field of view is 11 micrometers.*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with coal having high sulphur content, we believe omphalospheres are either indicative of high sulphur coals or a certain coal source. The only article we reviewed dealing with low sulphur coal (2) has several micrographs showing what appear to be omphalospheres. It is difficult to be sure because the loss in quality from print to reproduction in the article obscures the detail. On this basis, it is felt that omphalospheres are indicators of a high sulphur coal source.

Bottom ash tends to be somewhat more coarse than fly ash approaching sand size and consists mainly of scoriaceous material (micrograph 8) in which the vesicles are nearly always empty (micrograph 9). As shown in micrograph 9, there are some spherical bodies associated with bottom ash. These spherical bodies tend to be 3 to 10 times larger than fly ash and are less regular in shape. As shown in micrographs 10 and 11, these bottom ash spheres come in two morphologies. The least common of the two types is the scoria pseudosphere (micrograph 10). It consists of scoriaceous material in the shape of a sphere. It is very easy to distinguish from true fly ash spheres. The second and more common type is shown in micrograph 11. At lower magnifications these spheres look very much like fly ash spheres. However, at higher magnifications all resemblance between the two ceases (micrograph 12). Compare micrograph 12 with micrographs 6 and 7. It can be easily seen that the surface texture of the fly ash spheres are much smoother. Thus, the spheres of bottom ash characteristically have rougher surfaces and larger sizes.

In addition to the previously described morphologies, there is common to old and new fly and bottom ash an amount of amorphous material. This glass material is shown in Micrograph 13. Also, in bottom ash, clinkers are found in some abundance (micrograph 14).

MICROGRAPH 8: *This micrograph show typical bottom ash morphology. Note that it is more eoarse than fly ash and that the vesicles do not appear to be filled with cenospheres. The width of the field of view is 550 mierometers.*

MICROGRAPH 9: *This micrograph shows a closeup view of the surface of bottom ash scoriaceous material. Note that the vesicles are empty. The width of the field of view is 55 micrometers.*

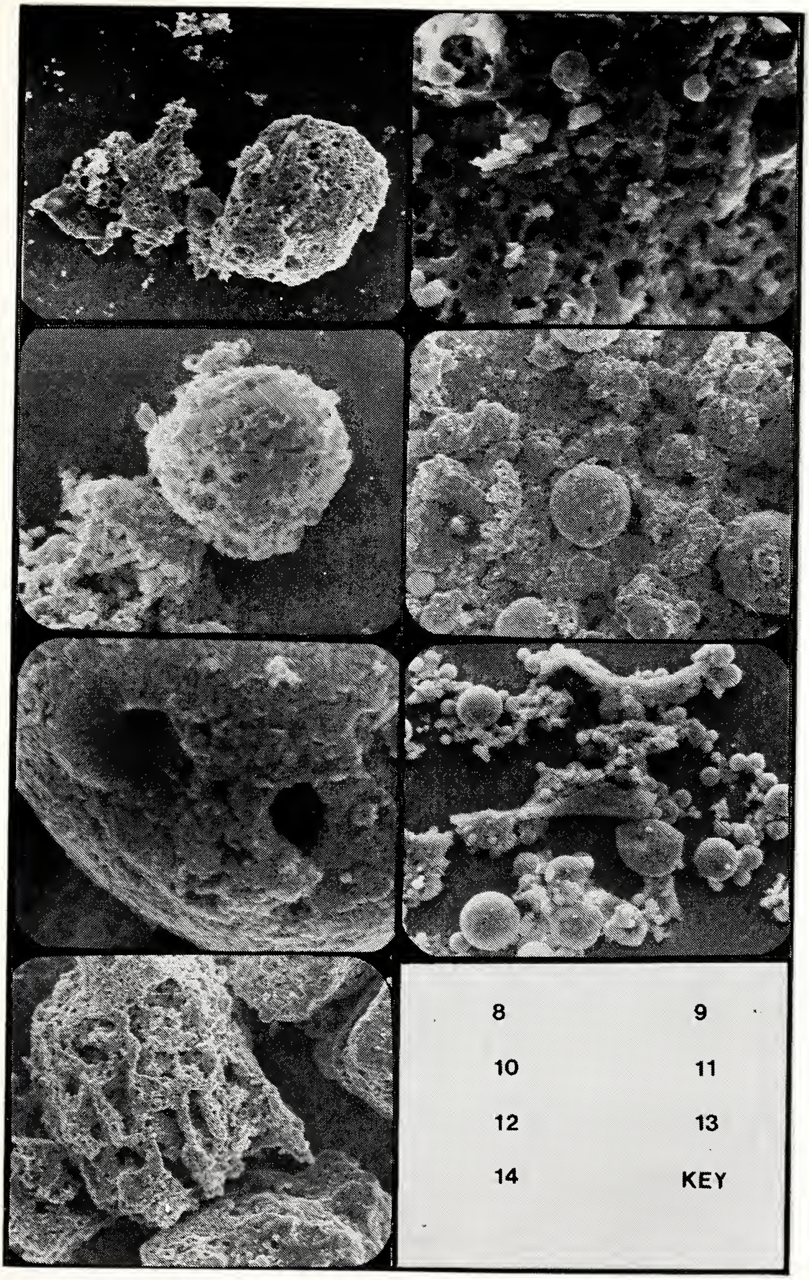
MICROGRAPH 10: *This micrograph shows a seoria pseudosphere from bottom ash. This is one type of sphere common to bottom ash. Comparing micrograph 10 with mierograph 6, one can see that it does not resemble fly ash. The width of the field of view is 110 micrometers.*

MICROGRAPH 11: *This micrograph shows the more eommon form of sphere common to bottom ash. Note that they are larger than most fly ash spheres. The width of the field of view is 550 micrometers.*

MICROGRAPH 12: *This micrograph shows a eloseup view of the bottom ash sphere in the center of micrograph 11. Note that at this higher magnification the surface of the sphere is much rougher than that of fly ash (compare with micrographs 5 and 6). The width of the field of view is 55 micrometers.*

MICROGRAPH 13: *This micrograph shows an amount of glass material which is common to both fly and bottom ash. This sample is from fly ash as can be determined from the abundance of cenospheres within the micrograph. The width of the field of view is 22 micrometers.*

MICROGRAPH 14: *This micrograph shows a bottom ash clinker. These elinkers are not eommon in fly ash. The width of the field of view is 550 micrometers.*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Conclusions

Fly and bottom ash morphologies and surface textures as seen with the SEM are quite indicative and can be distinguished from each other. In addition, certain morphologies (plerospheres and omphalospheres) may indicate a high sulphur coal source. The lack of crystalline overgrowths on our samples may indicate that crystalline overgrowths are a function of coal source rather than being common to all fly ash.

The morphologies found are enough different from those of stream and lake sediments that the SEM will be a useful tool in examination of stream and lake sediments for fly and bottom ash pollution.

References

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