Macroscopic inspection of cuttings and variations in consolidation state based on ultrasonic disaggregation, Hole C0002F

Nine cuttings samples (Table 1) in the 1 - 4 mm size fraction were inspected under the stereoscopic binocular microscope. Cuttings of silty mudstone can be categorized by shape, with 4 common categories being widely distributed, occurring in most samples (Table 2, Figure 1).

Cuttings shapes

**Rounded** cuttings and **wrinkled** cuttings are the most common types, and these are in general the dominant type in a given sample. **Faceted** cuttings are found in most samples and vary in abundance, but were not observed to dominate the cuttings assemblage. Very thin, platy cuttings and cuttings with prominent slickensides are varieties of faceted cuttings. Cuttings of distinctly **blocky** shape and cuttings that are composed of smaller fragments (**aggregate** cuttings) are not common, and are observed only in some samples. **Irregular** cuttings are those which do not fit into any of the categories above; these dominate in a few samples. Cuttings of sandstone, silty sandstone, siltstone, and clayey siltstone, display shape variations similar to ones described above, but not as distinctly.

The most distinct cuttings shapes are the faceted and wrinkled cuttings. Faceted cuttings are typically bounded by 4 to 5 flat to smoothly undulose faces that intersect along sharp, well-defined edges. Where slickensides are present, these structures are in most cases more strongly developed on one or two of the faces.

Wrinkled cuttings have a very distinctive appearance (Figure 2). On one side the mud takes the form of distinct parallel ridges. In a given fragment the ridges tend to be of very uniform thickness and spacing. The wrinkled face of the cutting may display a slight concavity and in well-developed examples, a raised medial ridge is oriented perpendicular to the parallel ridges (Figure 2C, 2D). Open spaces between the parallel ridges provide cavities that host sand and other disaggregated particles (Figure 2E). On the reverse side wrinkled cuttings are smooth and are either flat or display a slight convex curvature (Figure 2B, 2D, 2F, 2H) and in some cases faint striations that, like the medial ridge, are perpendicular to the parallel ridges. The smooth side of the wrinkled cuttings generally lacks any evidence of the ridges that are apparent on the other side. Wrinkled cuttings occur in most samples and dominate in many. Some rounded cuttings have faint traces of wrinkled structure.

Ultrasonic disaggregation

Examples of rounded, faceted, and wrinkled cuttings were collected from 2 samples for examination after ultrasonic sonication (Table 1, Figure 3). The fragments were placed in about 20 ml of distilled water and sonicated for 30 s (amplitude of 30 on the Q700 sonicator). Rounded cuttings were almost completely disaggregated by this treatment; wrinkled cuttings were disaggregated somewhat less, but still substantially. Stirring and another 30 s of sonication was enough to completely disaggregate the wrinkled cuttings. Faceted cuttings however were very difficult to disaggregate and remained largely intact, even after 1 minute of sonication.

Interpretation

These interpretations are tentative and in part speculative. Verification of these ideas will require further experimentation. Documentation and data from the bit manufacturer might readily clarify some of the issues.

Rounded cuttings, faceted cuttings, rare blocky cuttings (observed but not otherwise tested here), and wrinkled cuttings are all interpreted as somewhat modified, but largely intact fragments of silty mudstone. Only the rare aggregate fragments are interpreted as completely artificial mixtures of unrelated pieces of rock (induced aggregates).

Based on the contrasting behavior of the fragments under sonication, these different types may correspond to silty mudstones of differing consolidation state or disturbance during drilling, the rounded cuttings and wrinkled cuttings being softer than the faceted cuttings. The different shapes are plausibly interpreted as arising from the responses of materials of different hardness to the drilling, recovery, and cuttings washing processes.

The wrinkled cuttings may represent fragments that preserve a form created directly by the shearing/cutting action of the bit (Figure 4). The smooth, convex side is probably formed in contact with the bit as the mud fragment was sheared from the formation whereas the wrinkled side formed as the somewhat plastic mud was pushed away from the advancing cutting surface. The uniform thickness and spacing of the parallel ridges and their persistent occurrence and appearance across many samples argues against their origin as sedimentary laminae or layers. The open spaces between mud ridges trap many sand and silt-size fragments and clearly introduce a component of pore space into the bulk volume of the fragment. The abundant presence of these softer wrinkled cuttings in each sample might also explain the overestimation of the measured bulk porosity (see also section G. Physical properties and Fig. C0002F-G-F3).

Rounded cuttings probably take their form during the recovery and washing process as material is eroded from the softer lithologies. Faint evidence of wrinkled fabric in some rounded cuttings supports the notion that these form by erosional rounding of initially wrinkled cuttings during washing. Blocky cuttings may simply be reflections of sedimentary laminations or layering in somewhat harder material.

Faceted cuttings form from lithologies that have a distinctly greater degree of lithification. It is uncertain whether the observed association of slickensides with this form of fragment arises because deformation causes greater localized lithification or because shearing deformation is localized in harder rocks. In either case, it seems clear that these fragments have formed by brittle rather than plastic interactions during drilling.

Although there is no overt evidence that fragments other than the aggregate fragments are completely re-constituted from disaggregated sediment during drilling and processing, it is reasonable to assert that the wrinkled fragments are profoundly *remodeled* (but not re-mixed) material. They may have porosity in the bulk fragment that is higher than that in the original mudrock, as mentioned above.

Aggregate fragments vary in size and tend to be in the larger range of size. They are possibly clumps of material formed as the washed and sieved cuttings dried. Microscopic observation of each of these cuttings types could further clarify their character.

No attempt has been made to quantify the abundance of these cuttings types across the full sample set. The distinct forms of the cutting types however present an opportunity for cuttings characterization that could potentially reveal information on the stratigraphic distribution of rocks of contrasting mechanical properties.

Figure captions.

Figure 1. Major shape types of cuttings fragments observed in Hole C0002F. Scale is approximate. Magnification varies slightly across image set.

1. Rounded cuttings. 338 C0002F 311 SMW.
2. Rounded cuttings. 338 C0002F 126 SMW.
3. Faceted cuttings fragment. 338 C0002F 265 SMW.
4. Faceted cuttings fragment. 338 C0002F 311 SMW.
5. Wrinkled cuttings fragment. 338 C0002F 265 SMW.
6. Wrinkled cuttings fragment. Reverse side of fragment seen in image E. 338 C0002F 265 SMW.
7. Aggregate cuttings fragment. 338 C0002F 255 SMW.
8. Aggregate cuttings fragment. 338 C0002F 120 SMW.

Figure 2. Examples of wrinkled cuttings. Scale is approximate. Magnification varies slightly across image set.

1. Typical wrinkled cuttings. 338 C0002F 120 SMW.
2. Typical wrinkled cuttings. Reverse side of fragment seen in image A. 338 C0002F 120 SMW.
3. Wrinkled cuttings fragment with medial ridge. 338 C0002F 255 SMW.
4. Wrinkled cuttings fragment with medial ridge. Reverse side of fragment seen in image C. 338 C0002F 255 SMW.
5. Wrinkled cuttings fragment with sediment trapped in open spaces between the parallel ridges. 338 C0002
6. Wrinkled cuttings fragment with sediment trapped in open spaces between the parallel ridges. Reverse side of fragment seen in image E showing faint striations. 338 C0002F 311 SMW.
7. Wrinkled cuttings fragment with strong curvature. 338 C0002F 120 SMW.
8. Wrinkled cuttings fragment with strong curvature. Side view of fragment seen in image H. 338 C0002F 120 SMW.

Figure 3. Results of sonication experiment described in text. Faceted cuttings fragments resisted most disaggregation even after 1 minute of sonication. A similar amount of sonication almost completely disaggregates rounded and wrinkled cuttings.

Figure 4. Hypothetical model of production of wrinkled cuttings from interaction of plastic, semi-consolidated mud with the drilling bit. Not to scale. Cuttings fragments and wrinkles are very small relative to the bit teeth.