18. DRILLING-INDUCED STRUCTURES IN LEG 66 CORES[1]

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INTRODUCTION

In the early stages of Leg 66 drilling, regularly spaced parallel laminations in semi-indurated mud cores caused problems of interpretation for inexperienced shipboard sedimentologists, the writer included. Only after some time was clear evidence for a mechanical origin forthcoming. Lack of core lab or handbook documentation of these features, variously christened "drilling laminations," "drilling biscuits," or "Uncle Casey's cookies" by shipboard scientists, compounded the early problems. For this reason I decided to describe in some detail the range of drilling-induced features in Leg 66 cores in an attempt to identify geological conditions pertaining to their formation.

DESCRIPTION

Five varieties of drilling-induced features are recognizable (Fig. 1).

Bowed laminations (Figs. 1A, and 2) occur in the first recovered (unlithified) cores. They are well-known products of drilling deformation, produced by marginal downward deflection of original sedimentary laminations by descent of the bit and are considered no further here.

Drilling laminations (Figs. 1B, and 3). Horizontal laminations, 2 to 4 mm thick on average in most cases but rarely up to 10 mm, are common in cores retrieved from all sites landward of the trench. Similar laminations have been recorded in marl–marlstone cores from the Mediterranean (Leg 42, Kidd, 1978). Where present in Leg 66 cores, the laminations are generally spaced with extreme regularity (2–4 cm). Most display slight downward deflection at the margins; isolated laminations may deviate from the general rule of parallelism, being markedly concave downward (Fig. 3). Only rarely are laminations discontinuous. There is no noticeable difference in consistency between the laminations and the intervening material; in most cases both require firm pressure to yield thumbnail imprints. Nonetheless, smear slides show the material in the laminations to be consistently of finer grain size. In Leg 66 cores, laminations are of mud grade, the intervening material muddy silt. The laminations are in consequence always darker (medium dark gray to grayish olive green) than the normal core material.

Initial suspicion that the laminations were sedimentary derived from the lack of difference in hardness of the layers and was dispelled only by instances of laminations truncating burrows (Fig. 4) and inclined bedding.

Although drilling laminations do not occur in sand-rich sediment, they may be present in interbeds in sand-dominated cores (e.g., in Core 492-27, 5 and 6).

Drilling biscuits (Fig. 1C). In places laminations are softer than the remainder of the core and pass on each side into narrow zones of similar soft, smeared mud, which lines the inside of the core liner. In these cases the laminations separate more or less rectangular blocks, 2 to 4 cm and in rare cases up to 10 cm thick, of slightly coarser, indurated material. These discrete blocks, or drilling biscuits, are of unequivocal mechanical origin. In Hole 488 biscuits show marked lack of correspondence between magnetic inclination and declination within individual core sections, testifying to the rotation which must have occurred between them during coring (Niitsuma, this volume). Circular striae, similar to those recorded by Kidd (Leg 42, 1978), are visible on tops and bottoms of many of the extracted biscuits; these also indicate rotational movements.

Drilling biscuits, several centimeters thick on average, have also been recorded in mud–mudstone cores from the lower slope of the Japan Trench (Leg 57: e.g., Hole 440B, Core 4).

Core discs (Figs. 1D, and 5). Discrete, isolated discs, which may or may not be separated by a soupy matrix, are another category of drilling-induced feature. Discs are for the most part 3 to 5 cm. and rarely up to 10 cm thick, can occur as chains or as isolated examples, and are mostly rectangular in axial section. Truncated corners are fairly common, testifying to mechanical abrasion during rotation.

Drilling breccia (Figs. 1E, and 6). Breccia comprising angular chips of indurated mudstone floating in a soupy matrix is a local development in Leg 66 cores.

DISCUSSION

Drilling deformation has been plotted on logs of holes landward of the trench in Figure 7. From the data shown on these logs we can draw several conclusions:

1) The development of drilling lamination is controlled to some extent by bulk density and occurs mostly in sediment with bulk density between 1.9 g/cm^3 and 2.0 g/cm^3.

2) Because of this, the interval of semi-indurated sediment in which drilling lamination is prevalent depends on consolidation history and age, not on depth below the seafloor. Hence significant development of drilling lamination occurs at less than 100 meters downhole at Site 492 (in late Miocene sediment) but only at

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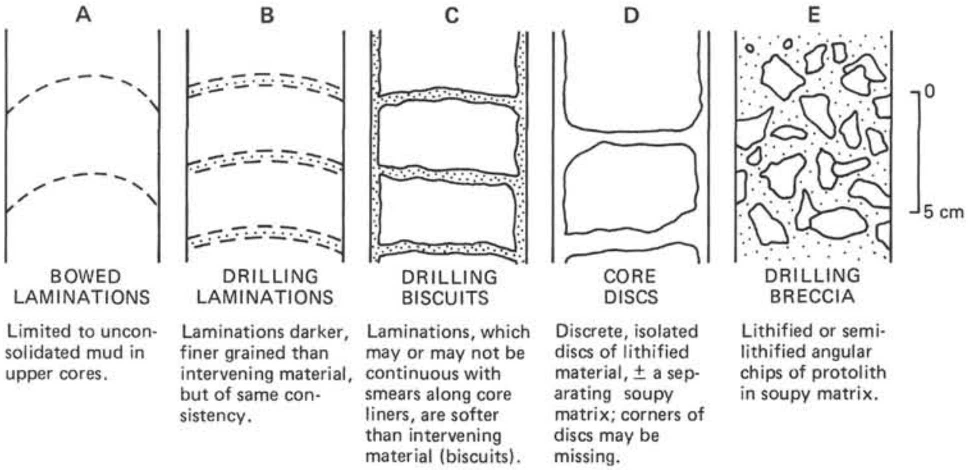

Figure 1. Types of drilling deformation in Leg 66 cores.

more than 200 meters downhole at Site 488 (in Quaternary sediment).

3) Core discing develops in general at deeper levels than drilling lamination, rarely occurring in sediment of bulk density less than 2.0 g/cm^3. In detail, however, there is often no clear downward progression from drilling lamination to core discing in individual holes, and the different deformation features can develop in the same core (Fig. 5).

4) The development of drilling lamination is not inhibited by the presence of inclined anisotropy in the core. The depth of significant (tectonic) deformation, defined as the level below which sedimentary dips in excess of 25° become common, occurs both well above and well below the first appearance of significant drilling lamination (e.g., Holes 491 and 490, respectively).

5) Drilling lamination and core discing do not occur in sand-rich cores. Apart from this, lithology is unimportant: finer grain sizes do not seem to show any preferential development of the features.

6) Pre-existing inclined fractures inhibit the development of drilling deformation (e.g., below 370 m in Hole 490; Fig. 8). Drilling lamination occurs only rarely in such zones (e.g., Hole 492, Cores 18–20), and core discing is limited to short intervals of core between inclined fractures.

7) Drilling deformation shows no obvious correlation with drilling rate or pump pressure.

8) Drilling breccia occurs in the better-lithified lower portions of cores. It is particularly common where recovered sediment has a high concentration of original inclined fractures (e.g., Hole 491). It is not clear in most cases to what extent drilling has caused further disruption in a zone of original brecciation (e.g., mud-chip sedimentary breccia or fault shatter zone). In some instances, however, gradational tops of breccia zones (Fig. 6) and "incipient" brecciation (Fig. 9) suggest that some facet of drilling technique is responsible.

It appears that drilling laminations and core discs form the end members of a continuous spectrum of drilling deformation, depending in general on the lithification state of the initial sediment: drilling laminations are characteristic of semi-indurated mud; core discs tend to develop in indurated mudstone. Kidd (1978, p. 1144) has ascribed the core discing in Leg 42 sediments to a process familiar in the drilling industry: a hammer-and-bounce effect produced when considerable weight is required on the bit to core stiff lithologies (especially waxy clays). Francis (in press) has suggested that lateral oscillations of the drill string may in certain circumstances build up, causing the core to be broken into a series of small pieces.

What is not clear at present is how material of the same consistency but of finer grain size than the protolith becomes concentrated in several millimeter thick drilling laminations.

REFERENCES

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Kidd, R. B., 1978. Core-discing and other drilling effects in DSDP Leg 42A Mediterranean sediment cores. *In* Hsü, K., Montadert, L., et al., *Init. Repts. DSDP*, 42, Pt. 1: Washington (U.S. Govt. Printing Office), 1143–1149.

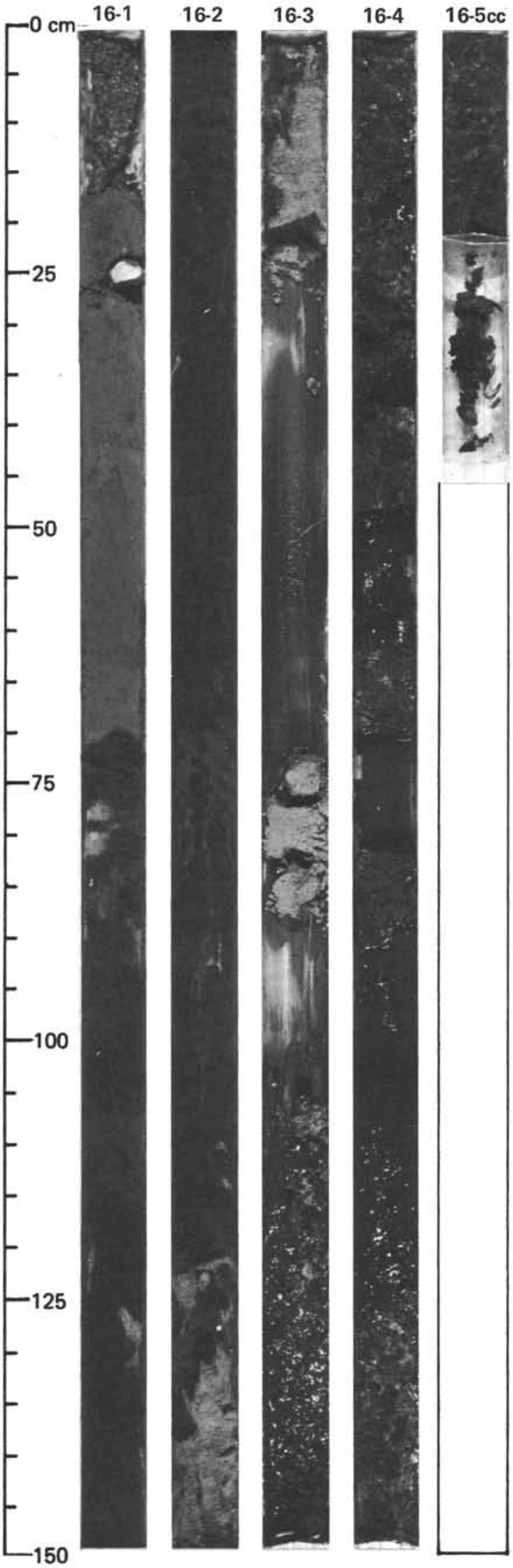


Figure 2. Bowed lamination illustrated by a color change in Pliocene brown and gray clays (Sample 487-16-1, 35–115 cm).

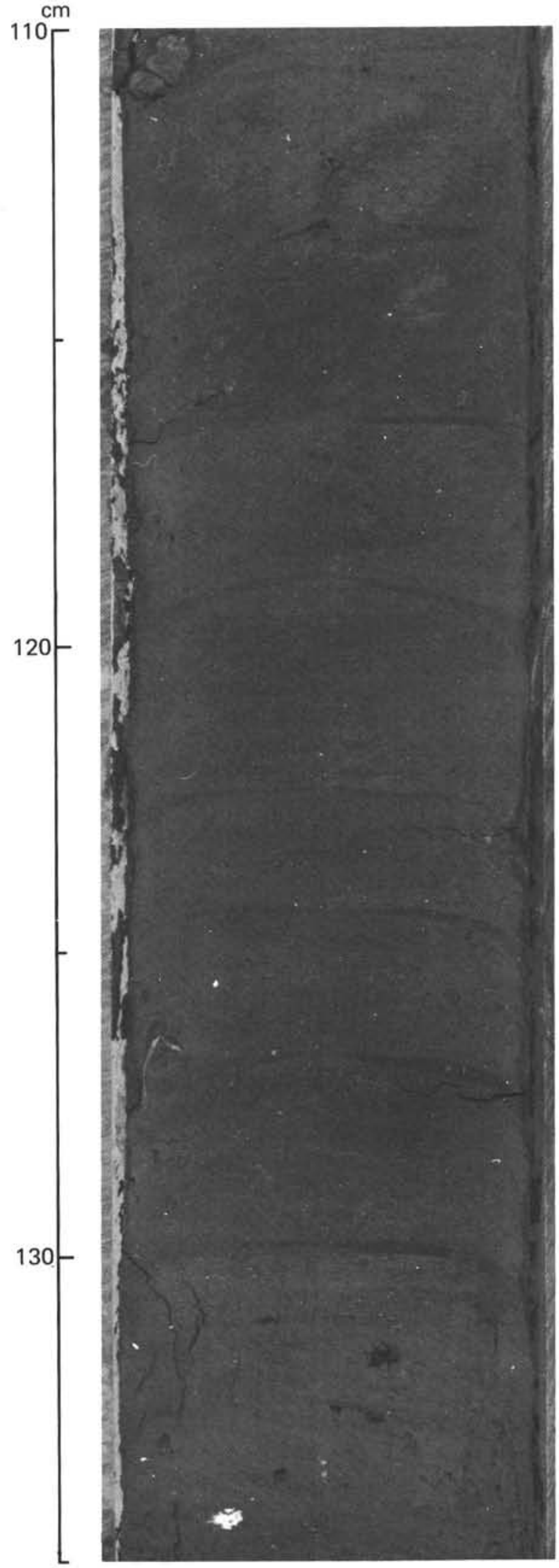


Figure 3. Drilling laminations: Note upward warp of central lamination. This is fairly unusual, because laminations are usually parallel (Sample 488-30-1, 110–135 cm).

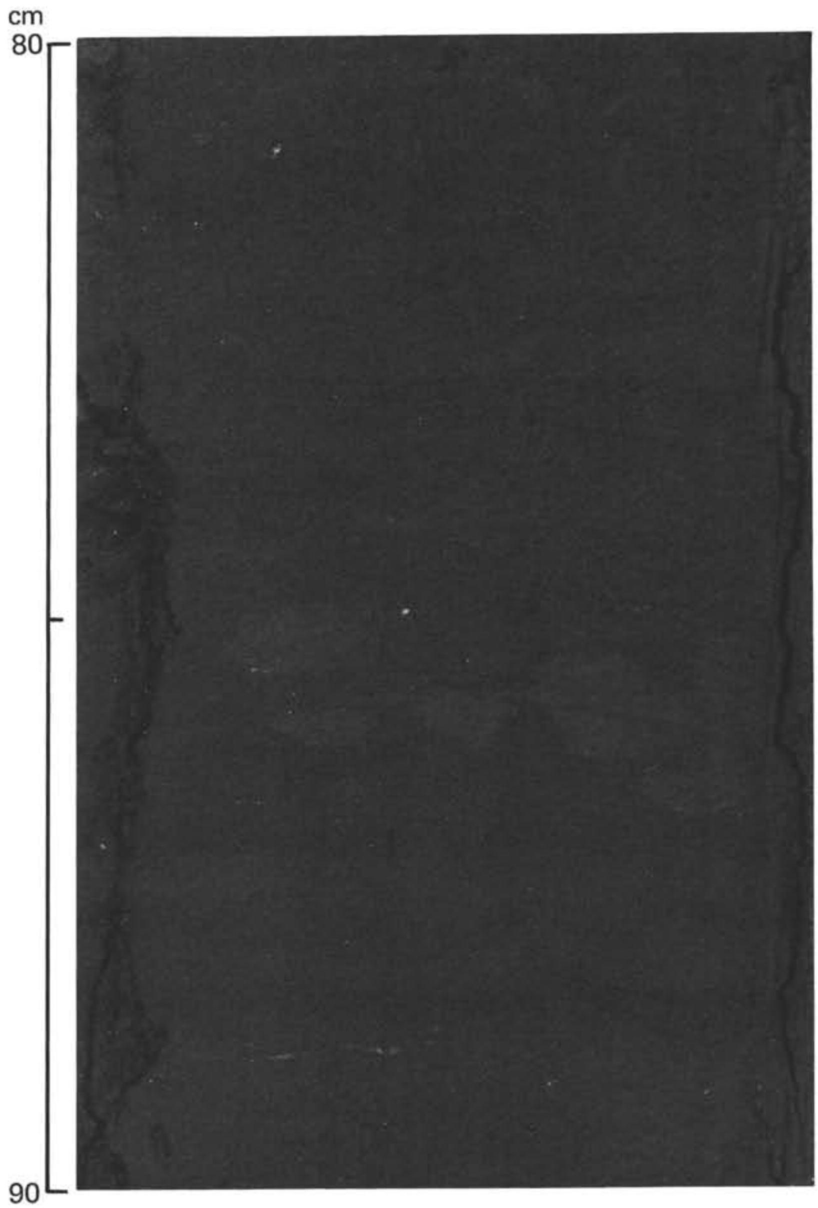


Figure 4. Drilling lamination truncating burrow system. Smearing of burrow indicates that rotation has occurred along the lamination despite similar consistency of the lamination and remainder of sediment (Sample 490-20-5, 80–90 cm).

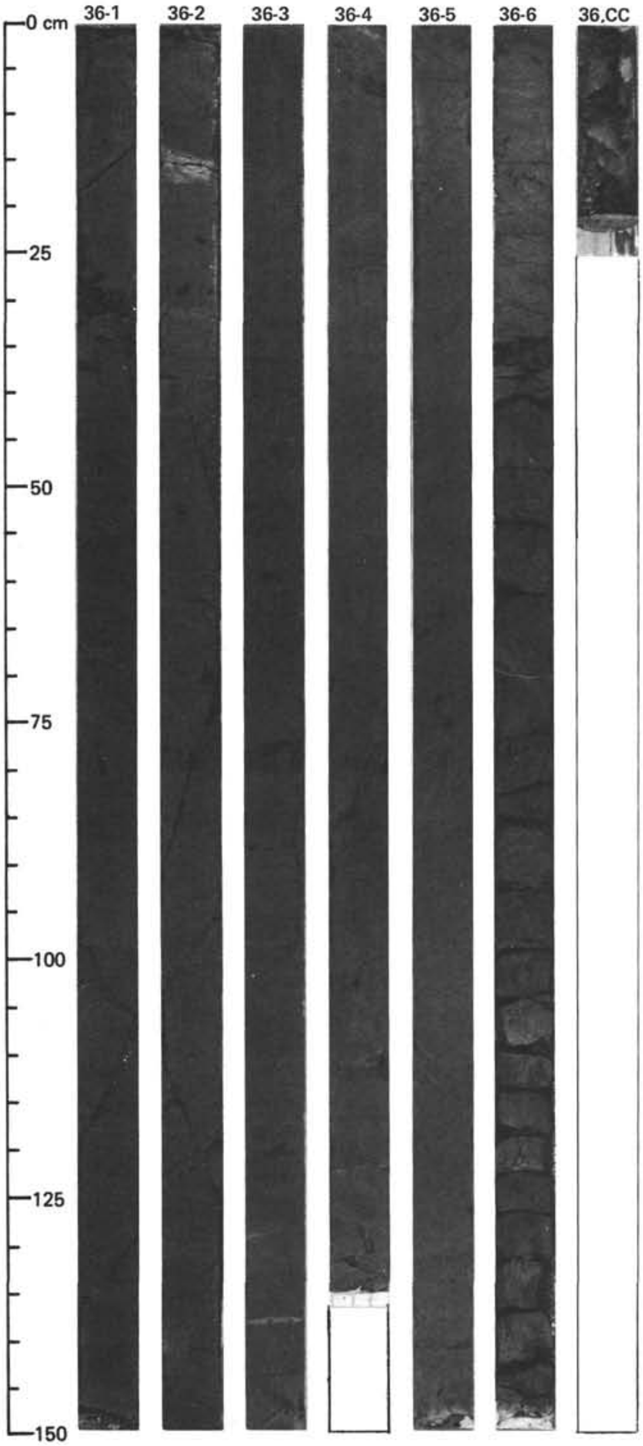


Figure 5. Drilling lamination and core discing in the same core (Section 490-36-6).

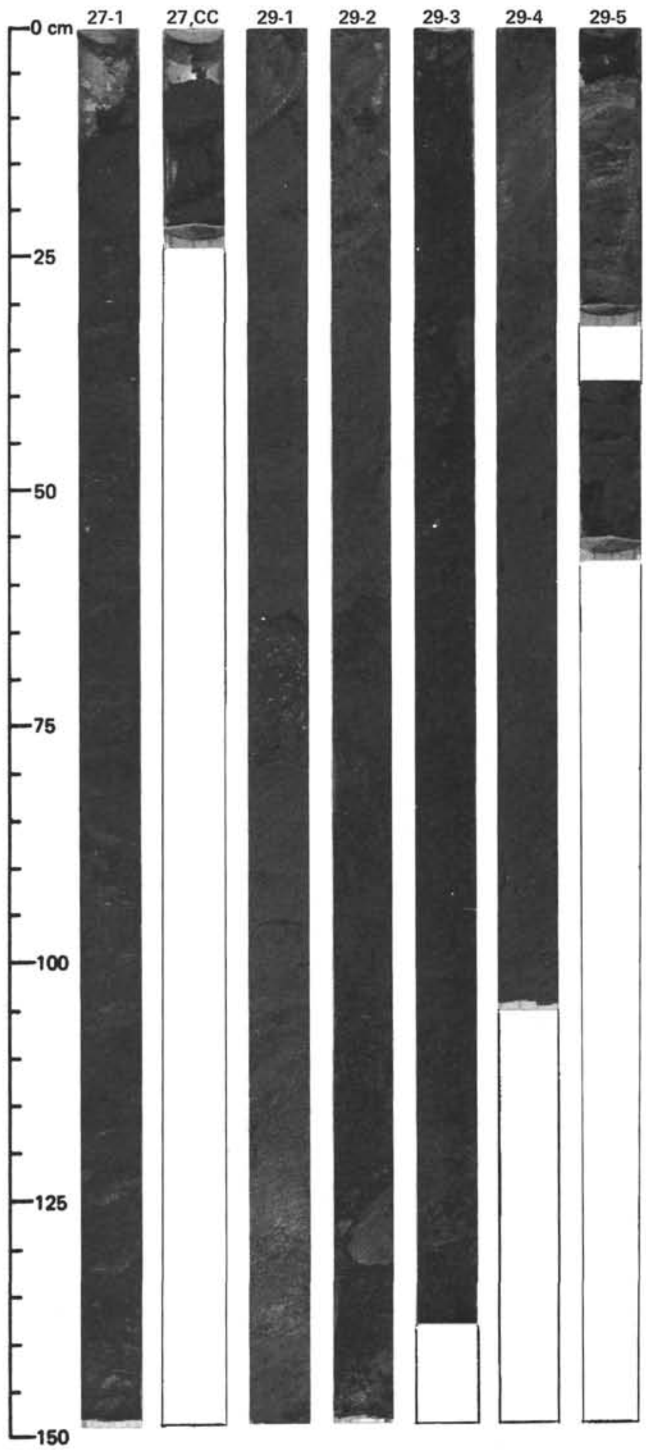
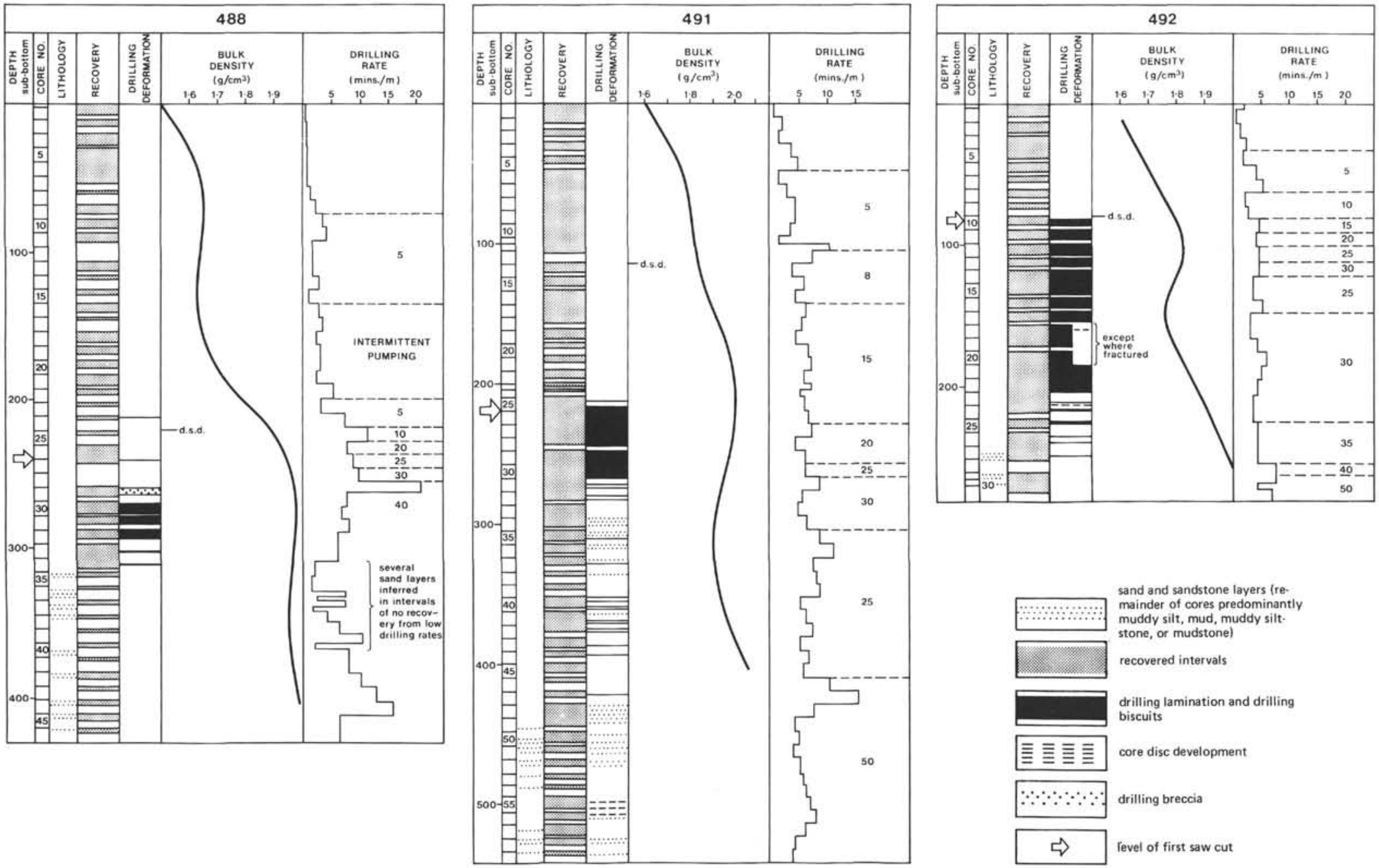


Figure 6. Drilling breccia with gradational top (488, 29, 1-4).


488
491
492
DEPTH sub-bottom
CORE NO.
LITHOLOGY
RECOVERY
DRILLING DEFORMATION
BULK DENSITY (g/cm³)
DRILLING RATE (mins./m)
d.s.d.
INTERMITTENT PUMPING
several sand layers inferred in intervals of no recovery from low drilling rates
except where fractured
sand and sandstone layers (remainder of cores predominantly muddy silt, mud, muddy siltstone, or mudstone)
recovered intervals
drilling lamination and drilling biscuits
core disc development
drilling breccia
level of first saw cut

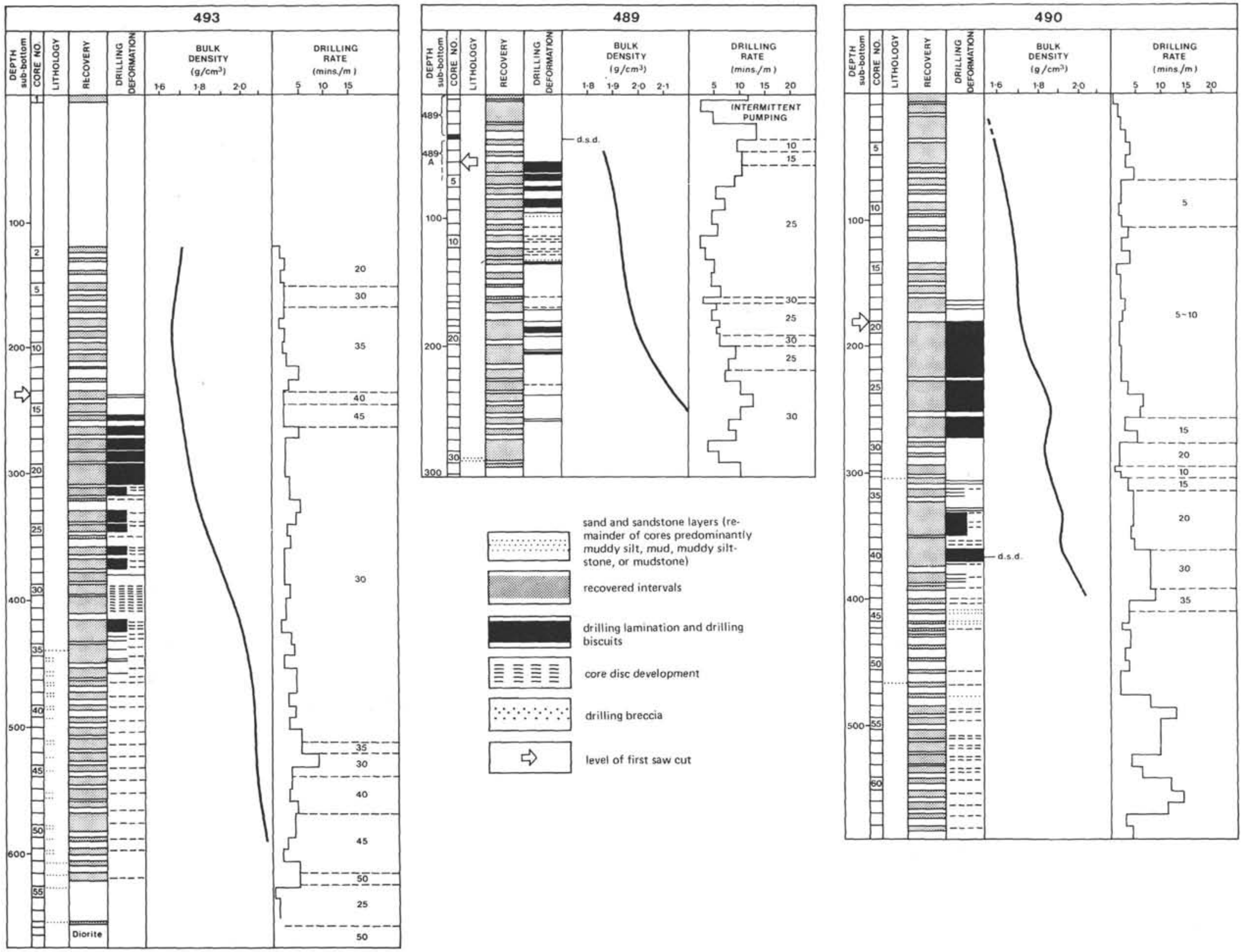


Figure 7. Drilling deformation development in Leg 66 holes. (Where individual cores show both drilling lamination and core discing, half the column width is used to illustrate the development of each category. Bulk density curve is a best fit line drawn through numerous shipboard data points and is therefore only a general guide to lithification at any level. d.s.d = depth of significant deformation [defined as the repeated occurrence of dips greater than 25° and in general also demarking the downhole appearance of discrete inclined fractures and zones of stratal discontinuity]. Pumping pressure shown next to drilling rate histogram [figures in strokes per minute].)

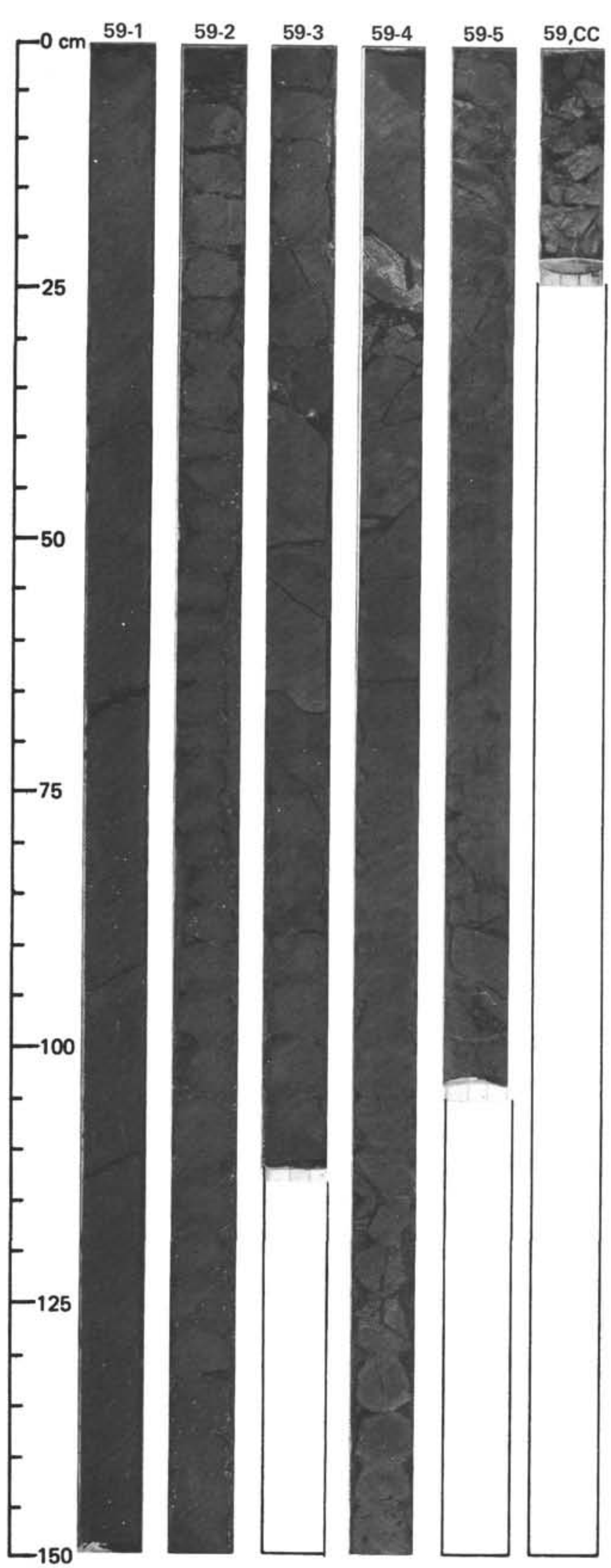


Figure 8. Inclined fractures (Core 490-59, Sections 1–4).

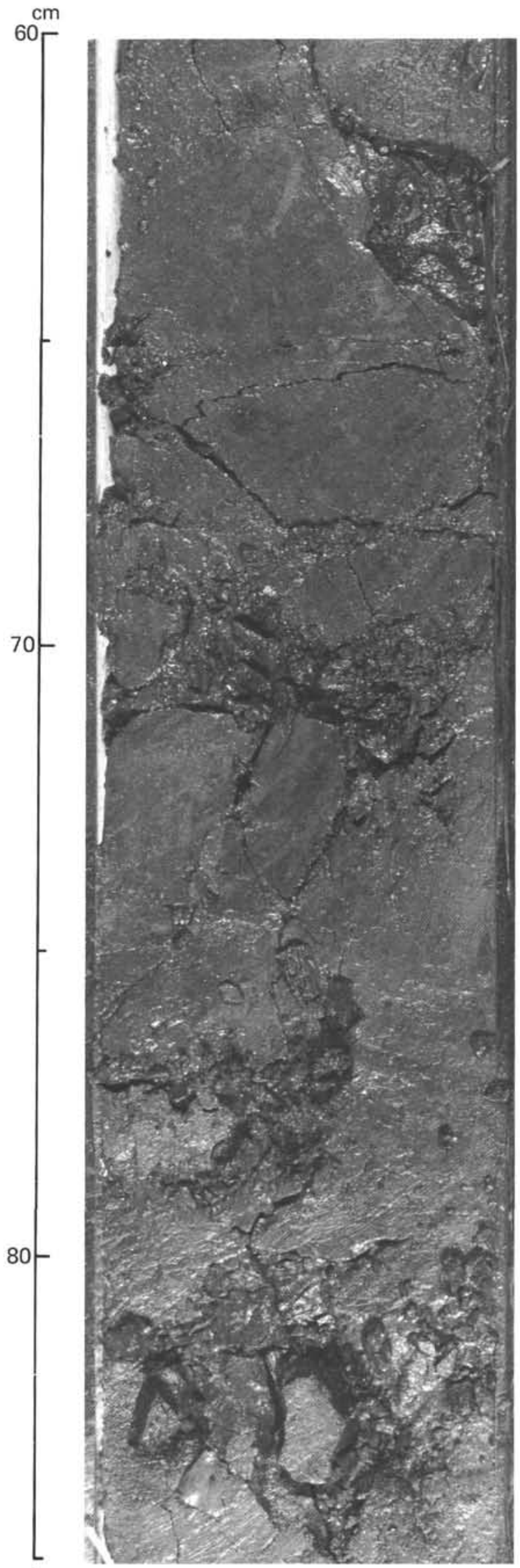


Figure 9. Incipient drilling breccia (Sample 489A-8-2, 60–85 cm).