

and a variety of other functions. Many microprocessors now provide FORTRAN IV programming capabilities.

Because raw data and statistical data are stored on disks, either data set can be analyzed at any time or using any statistical technique. Many microprocessing terminals and CRT's can be linked directly to large computers and the data transferred from one system to the other by either a modem or direct line.

Identical sediment samples were analyzed a number of times to test reproducibility of the system. Analyses were performed by different people, and a five-fold sample size range (from 200 mg to 1.0 grams) was used. Variation in mean grain size for the large tube is on the order of 1%, and on the order of 5% for the small tube.

ACKNOWLEDGMENTS

Financial Aid for this project was made available through grants from the National Science Foundation (NSF Equipment Grant—SER-77-11222) the American Chemical Society—Petroleum Research Fund (Grant PRF-9472-AC2), the Environmental

Protection Agency through Interagency Energy Agreements No. EPA-1AG-D5, D6 and D7-E693-EO and from Rice University. We thank Don Jarvis, Glenn Fryer, Bill Behrens, and Larry McCormick for the assistance in the design of the instrument.

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METHOD FOR SILT AND SAND FABRIC ANALYSIS IN DEEP-SEA CORES¹

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ABSTRACT: A method is described for the palaeomagnetic orientation of soft sediment cores to geographical north and the measurement of grain orientation in thin silt laminae and sand layers using a Scanning Electron Microscope.

Successful application of this method to cores from the deep water margin of Nova Scotia permits a distinction between coarse layers deposited by *downslope* currents and those reworked by *alongslope* currents.

INTRODUCTION

The study of sediment fabric has proved very useful in determining the direction of

ancient currents and the depositional environment of ancient sands and gravels (Potter and Pettijohn, 1963; Middleton, 1965). However, there have been very few fabric studies of offshore recent sediments (Rees et al, 1968; Piper, 1973), largely because of methodological problems. Firstly, geographical orientation of the sediment samples is

¹Manuscript received April 7, 1978; revised June 15, 1978.

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necessary. This can be achieved using diver recovery in shallow water, and locking compasses or photography for deep water box coring (Rosfelder and Marshall, 1966). But, core rotation during piston or gravity coring (McCoy and Von Herzen, 1971; Stow and Aksu, 1978) makes these methods inaccurate in deep water. Secondly, laboratory techniques for fabric analysis, especially of fine-grained sediments, are not yet well developed (but see Carver, 1971).

This paper describes a relatively simple method for the analysis of grain fabric in silt laminae and fine sand layers from deep-sea piston cores, and for the orientation of cores to geographical north. The method has been applied successfully to cores from the outer margin off Nova Scotia, Canada and some of the results of this study are also discussed.

METHOD

Orientation of Cores

Sediment plugs are taken from a split core for palaeomagnetic measurement using short lengths of perspex tubing, and are carefully marked for orientation with respect to the core. The sample interval should be small (say 5 to 20 cm) and the core section smooth and undisturbed. Magnetic polarity is measured on a DSM-1 Digital Spinner Magnetometer before and after demagnetizing at 50, 100, 200, 300, 400 and 500 Oersted. If the field is found to stabilize consistently at a particular value, then samples can be routinely demagnetized to this value before spinning.

Where the palaeomagnetic declination shows little downcore variation then, assuming an axial dipole field, the mean value of declination can be taken as geographical north (Ellwood and Ledbetter, 1976, 1977). Rotated core sections will show a systematic change in declination value (Stow and Aksu, 1978), and an attempt may be made to compensate for this rotation in the orientation of the core. For the purpose of accuracy, samples from rotated core sections should not be used for fabric analysis.

Fabric Study

Following the measurement of remanent magnetism the sediment plugs are gently

pushed out of their containers and left to dry for a few days. During drying, the samples break naturally along the main silt partings so that undisturbed surfaces of silt laminae (i.e. bedding planes) can be examined under a binocular microscope. The direction of prominent current lineations (if present) are measured, and samples showing bioturbation may be discarded. Small pieces of silt laminae are mounted, surface-up, on SEM stubs using silver paint, having carefully noted their orientation with respect to the sediment plugs.

Each silt lamina within a particular (cylindrical) plug is rectangular in outline; a corner chip with two perpendicular, straight edges can, therefore be easily related to the plug orientation. These silt chips are then coated with carbon and gold for examination on a Scanning Electron Microscope, at magnifications usually between 200 and 1000. The axes of long grains (length to width ratio greater than 2:1) are traced onto a transparent overlay placed on the viewing screen. All long grains (say 200–300) from one or several random traverses should be marked, using two or three overlays to avoid overcrowding. Often, only a small proportion (5–30%) of grains in any one layer are suitable for measurement. The bulbous ends of "pear-shaped" grains can also be noted. The grain orientations are then measured from the overlay and plotted as rose diagrams for each laminae with respect to the recalculated geographical north of that core. The thicker silt laminae may be mounted perpendicular to the bedding to measure grain orientation perpendicular to the bedding plane, and thus to observe any imbrication present.

Plugs of sandy sediment become loose when dry and are not suitable for examination under the Scanning Electron Microscope. They are left in their containers and impregnated with bioplastic resin (Bouma, 1969; Stanley, 1971) for sectioning parallel and perpendicular to the bedding. Thin sections are examined on a Shadowmaster Slide Projector and grain axes marked on a transparent overlay as before.

Accuracy

Disturbed or bioturbated laminae, and rotated core sections are best avoided. Fine, clay-rich muds suffer shrinkage and probable

fabric distortion during drying, while coarser, silt-laminated muds do not. The palaeomagnetic measurements are accurate to within a few degrees, and the orientation of cores using mean declination values appears valid when they show little downcore variation. The main source of error is introduced by the operator when trying to maintain correct orientation during sub-sampling and measurement. However, several of the Scotian margin cores had been marked with a single, continuous scribe line before being cut into 1.5 m sections for easier handling. Random splitting of cores naturally rotated the core sections with respect to each other. Subsequent palaeomagnetic alignment of these sections matched to within 5–10° that obtained by joining scribe lines. Comparison of results from the measurement of both current lineation and grain orientation for the same laminae revealed a discrepancy of only 5° in the estimated current direction.

SOME RESULTS AND DISCUSSION

The orientation of long grains parallel to the bedding was measured in more than 80 silt and sand layers from 6 oriented Scotian margin cores (Stow, 1977a). An X-radiograph of the typical silt-laminated mud facies is shown in Figure 1; layers are commonly between 2 and 10 mm thick. Three fabric types were most commonly encountered: those with a single preferred orientation (Fig. 2a); a bimodal distribution of less than 20° on either side of the mean orientation (Fig. 2b); or a widely bimodal distribution with a difference of 70° to 80° between the dominant and secondary modes (Fig. 2c). The best orientations were found in the coarsest silt laminae, while some of the finest laminae showed more random distributions. A limited number of measurements were made perpendicular to the bedding and these indicated some tendency towards orientation parallel to the bedding plane, but with no clear imbrication.

There has been very little work previously on the grain fabric of silt sized material (Piper, 1972). Various studies have been made, however, on the anisotropy of magnetic susceptibility in modern and ancient sediments (Hamilton, 1963; Rees, 1965) as well as in experimentally deposited silts (Rees, 1966; Hamilton, 1967). Their evidence

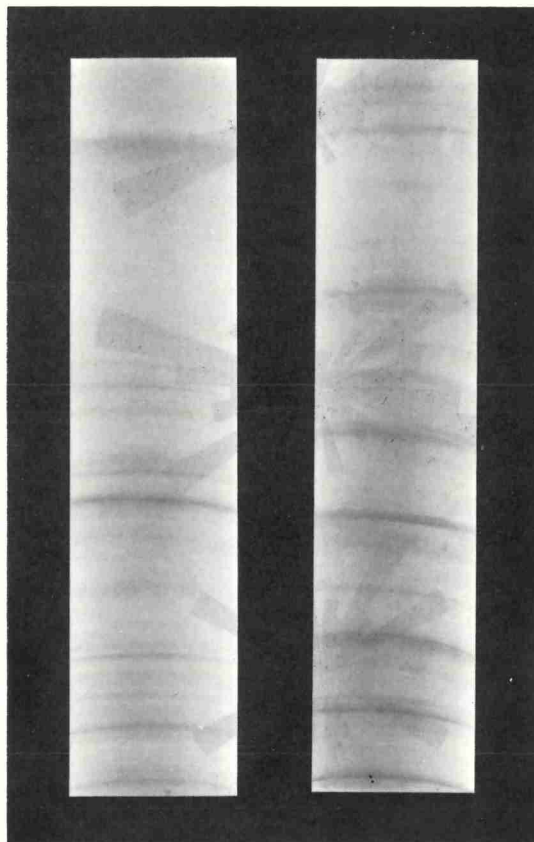


FIG. 1.—X-radiograph print of silt laminated mud in cores from the Laurentian Fan off Nova Scotia. The width of the core section is about 5 cm. The dark layers are silt laminae.

suggests that the entire silt-size range of non-magnetic grains will be oriented parallel to the current direction when deposited from flowing water. Piper (1973) and Piper and Brisco (1975) found an orientation parallel to the bedding but without imbrication in both turbidite and contourite silts from the Gulf of Alaska and Antarctic Ocean.

It may therefore be assumed that the preferred orientations in the Scotian margin cores represent current directions (an inference supported by the parallelism of grain orientation and current lineation). Consideration of the geographical orientation of the cores shows that most of the silt laminae were deposited from approximately north-south (downslope) currents. Other coarse layers show east-west (alongslope) or widely bimodal orientations, some with dominant

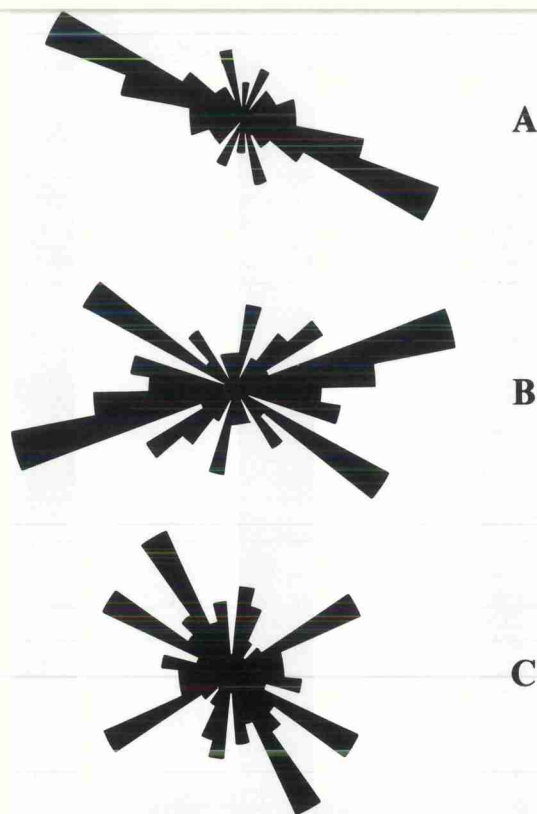


FIG. 2.—Rose diagrams of silt laminae fabric. Orientations of long grains (between 150 and 200) were measured parallel to the bedding plane. a) Single preferred orientation. b) Narrow bimodal distribution on either side of mean orientation. c) Single preferred orientation superimposed on narrow bimodal distribution giving widely bimodal mean orientation directions.

east-west and subordinate north-south directions evident. These results may be used to distinguish between fine-grained turbidites and contourites on the outer Scotian margin (Stow, 1977b).

ACKNOWLEDGMENTS

This work was supported by National Research Council (Canada) and Imperial Oil research grants to David J. W. Piper. Ilfryn Price is thanked for useful criticism of the manuscript.

The British National Oil Corporation provided technical assistance in the final preparation of this paper.

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