COMPARISON OF MICROFOSSIL/SEDIMENT SEPARATIONS PERFORMED BY TWO MAGNETIC SEPARATION SYSTEMS

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Abstract

To test the efficacy of two commercial magnetic separators, the Frantz Isodynamic Magnetic Separator Model L1 and The Intermagnetics General Corporation's Magstream Model 100, for isolating foraminifera and other shelly microfossils from mineral grains, replicate well cuttings samples were processed in both machines.

The fractions isolated by the instruments were microscopically examined and compared to picked microfossil slides previously made from the samples in order to assess the capability of the two machines. These were challenging samples, since the target fossils in the samples included a range of grain sizes and shapes. More importantly, the fossils exhibited a range of compositions, from calcium carbonate to siliceous and even pyritic in some cases.

Results indicated that neither machine was able to perform a completely efficient separation with all the fossils concentrated in one mineral-free split. Some success was achieved by both systems in some samples, but both also had little success with others. Performance of the instruments on each sample was judged on the relative sizes of the fossiliferous and non-fossiliferous fractions. Ideally, all fossils should be concentrated in one fraction, with little or no mineral matter.

Since the two test instruments are quite different in many respects, including mode of operation, it is not possible to arbitrarily state that one is inherently better than the other for sediment/microfossil separation.

Introduction

Magnetic separation devices of several kinds have been used to concentrate microfossils in sediment samples for over forty years (Schmidt, 1948; Dow, 1960; Eckert et al., 1961), and are a standard procedure in some laboratories (Allman and Lawrence, 1972).

All magnetic separation systems rely on the differing chemical composition of the mineral grains and microfossil tests in samples. Different compositions produce different magnetic susceptibilities, which can then be exploited to separate the various components. Foraminifera, being for the most part calcitic, exhibit no magnetic susceptibility and so can theoretically be separated from the heavy minerals, glauconites and shale fragments that make up most samples. Magnetic separation can thus reduce the amount of hand picking required for such material.

Recently discussions were held at the Atlantic Geoscience Centre (AGC) on the advisability of purchasing such equipment for use in house in various sedimentological studies and mineral analyses as well as routine concentrations of microfossils from offshore well samples.

Since there are, apparently, no Canadian producers of such instruments, it was decided to assess the capabilities of models built by two of the better-known American manufacturers. To this end, replicate samples were sent to the Centre for Cold Ocean Resources Engineering (C-CORE) at Memorial University of Newfoundland in St. John's, who operate a Frantz Isodynamic Magnetic Separator Model L1 , and to Intermagnetics General Corporation of Guilderland, New York, U.S.A., manufacturers of the Magstream line of separators.

Methods

Many micropaleontology samples routinely studied by personnel at A.G.C. are ditch cuttings from offshore hydrocarbon exploration wells. Most are hand-picked at considerable expense and effort. These samples are normally processed from the raw material using the "industrial soap" method described by Thomas and Murney (1985). The processing takes place in the Canadian Oil and Gas Lands Administration laboratories at the Bedford Institute of Oceanography, and ends with the samples being washed through a 63-micron sieve and dried.

The resulting residues are usually composed of a mixture of undisaggregated lithic fragments (usually shale, marl or limestone), mineral grains such as quartz, feldspars and heavy minerals, and shelly microfossils such as foraminifera,ostracodes, small fragments of mollusc shell, and, occasionally, pyritized diatoms. The composition of the individual fossils is just as varied, ranging from pure calcite in unaltered foraminifera and ostracodes to siliceous agglutinated foraminiferal tests, silica replaced foraminifera, and pyritized casts of diatoms, pteropods and foraminifera. Also present in some samples are magnesium rich calcite fossils such as echinoderm fragments and phosphatic fish teeth. Some of these non-foraminiferal microfossils are of stratigraphic interest to researchers on the eastern Canadian margin (Thomas and Gradstein,1981).

For purposes of experimentation, five samples were chosen from different wells on the basis of fossil content. The strategy was to collect a group of samples which would contain a representative assortment of fossil types, exhibiting various modes of preservation and mineralization, along with variances in fossil size and abundances. Arguably, five samples is not a very large number for any sort of comparative qualitative analysis, but it was felt that in the interests of obtaining the best cooperation from outside organizations, demands on their time should be kept to a minimum. The five samples chosen are listed in Table 1.

This material was then subsampled and a portion of each sent to the locations described above.

Frantz Isodynamic Separator

The Frantz machine (fig.1) incorporates a large electromagnet which produces a powerful field through which the sample is passed. Usually the magnet is positioned at a slight downward angle so that the mechanism is gravity-fed, with the feed hopper at the upper end and the receptacles for the magnetic and non-magnetic fractions at the lower end. A strong coaxial vibrator keeps the sample particles in constant motion while passing through the field. Near the bottom the channel through which the particles flow is bifurcated; magnetic particles are pushed to the outside by the repellant action of the magnet, while non-magnetic ones remain in the inside portion of the track. A slight back-to-front dip of a few degrees helps to prevent non-magnetic grains from finding their way to the outside track through random motion. The current supplied to the electromagnet is variable, to a maximum of 1.8 amperes.

At C-CORE, 4 of the 5 samples were processed with instrument settings at 3 degrees dip back-to-front, 15 degrees tilt down and 1.5 amps current. Each sample was run through twice to improve the separation. The sample from Penobscot B-41 was too coarse initially, so was sieved to yield a 63-180 micron size fraction, then processed in the same way.

Intermagnetics General Corporation

The I.G.C. Magstream Model 100 (fig. 2) differentiates mineral grains on the basis of specific gravity as well as magnetic susceptibility. In this instrument, samples suspended in a a magnetic fluid (Magfluid™) are poured down a rapidly rotating tube. A magnetic field around the tube helps draw the fluid and magnetically susceptible particles toward the perimeter of the tube. Less susceptible particles become "buoyant" and stay nearer the center of the tube. By adjusting the specific gravity of the fluid, separations based on any specific gravity are theoretically possible. Near the bottom of the tube a knife-edged circular divider separates the two fractions, which are collected in containers below (Intermagnetics General Corporation, 1988).

At I.G.C. each of the five samples submitted were weighed and examined under a binocular microscope to estimate the volume of microfossils as well as their form and composition , as all of these variables are important to proper processing. Also, the mineralogy of each sample was determined using a petrographic microscope. Ferromagnetic and strongly paramagnetic grains were then removed with a hand magnet. Finally, each sample was suspended in Magfluid™ and separated in the instrument at successive specific gravity split points of 2.50, 2.63 and 2.90 by changing the amount of time the sample/water slurry was left in the spinning tube. Afterwards the various splits were dried and weighed. Since in this process the samples were suspended in a liquid, small amounts of each were lost, presumably as shale fragments disintegrated into clay and remained in suspension.

When both sets of samples were returned to A.G.C., every fraction of each sample was examined under a binocular microscope and the content and composition of the fossils therein were noted. Since hand'picked microfossil slides from the samples already existed in Geological Survey of

Canada archives, comparisons to the microfossil assemblages in the separated fractions could readily be drawn.

Results

Examination of the fractions enabled detailed comparisons of the abilities of the two separation instruments on a sample by sample basis.

Moheida P-15, 8330-8360' - the archived G.S.C. slide contained a rich and abundant assemblage of calcareous and agglutinated foraminifera.

This sample was not analysed by the Frantz machine. Examination of the separated fractions produced by the I.G.C. instrument (table 2) revealed numbers of fossils of both types in each, and there appeared to be no significant concentration of microfossils in any fraction.

Penobscot B-41, 3980-4010' - the picked slide of this sample contained a relatively impoverished fauna of calcareous foraminifera and a few pyritzed tubes, probably representing small infilled burrows.

This sample had to be sieved for analysis in the Frantz unit, and only the <180 micron fraction was used, thereby eliminating the larger fossils at the outset. In the separation, most fossils, including calcareous foraminifera, ended in the "magnetic" portion, along with various types of mineral grains, some pyritized tubes, and a few foraminifera which appear to have been replaced with silica. The non-magnetic fraction contained only fine sand-sized quartz grains, a few small calcareous fragments and a few very small fossils. Since in this instance most fossils were found in a portion representing over 70% of the original weight of the sample, it was not considered an effective separation.

Migrant N-20, 3380-3410' - the picked slide of this sample contained abundant calcareous foraminifera and a few agglutinated ones.

Separation with the Frantz unit resulted in effective concentration of shale fragments in the magnetic portion, but fossils and quartz grains were more or less equally dispersed through both splits, so a good separation of fossils was not achieved. The I.G.C. machine's four fractions all contained some fossils, but more were found in the <2.63 s.g. portion than any other. Since this portion represented only 15.4% by weight of the total sample, this was considered a partially effective process.

Skolp E-07, 2425-2435m - the archived picked slide representing this sample contained abundant recrystallized agglutinated foraminifera along with a few calcareous ones.

The Frantz machine achieved a reasonable separation with this sample, concentrating the majority of fossils in the magnetic fraction, which represented only 30.1% by weight of the original sample. All four splits created by the I.G.C. instrument contained some fossils, so it was not considered a good separation.

Roberval K-62, 1265-1275m - the picked slide of this sample contained an impoverished assemblage, with only small numbers of foraminifera including calcareous, pyrite-filled calcareous and agglutinated siliceous specimens.

The Frantz unit divided the sample into a non-magnetic portion (90.3% by weight) containing quartz and other "light" minerals and a few calcareous fossils. The much smaller magnetic part contained most of the fossils, thereby achieving a reasonably good separation. All four of the I.G.C. instrument's splits contained very small numbers of fossils, but considering the poor nature of the sample to begin with, these results are inconclusive. Interestingly, the mineral grains in this sample did not appear to have been well sorted in the process either. In the four samples other than Roberval processed by the I.G.C. machine each of the four splits appeared progressively darker from <2.50 s.g. to >2.90 s.g., as more and more heavy mineral grains appeared, evidence of the sensitivity of the separation.

Discussion

A subjective assessment of the comparative performance of the two machines is given in Table 4. This appraisal is based on whether the equipment was able to produce a concentration of microfossils in a substantially reduced portion of the original sample, although in no case was there a completely successful attempt, i.e. with all microfossils separated from all mineral grains.

One of the most difficult problems encountered in any magnetic susceptibility or specific gravity separation is the variety of compositions of microfossils within many samples. The ditch cuttings used for these tests are composite samples and may include material representing several lithologies and modes of preservation. Outcrop samples of a more homogenous nature, particularly Quaternary material where recrystallization and replacement of fossils is rare, would probably produce better results with these and similar instruments.

Eckert et al. (1961) described a method to enhance the separation of calcareous microfossils in an isodynamic magnetic separator such as the Frantz instrument. In this procedure the non-magnetic split produced by the first pass , which should contain the microfossils along with quartz and other non-magnetic minerals, is soaked briefly in a weak (2-5%) solution of ferric chloride. This causes the calcareous material to assume a thin coating of iron, and a second pass through the machine will then separate these "magnetic" fossils from the minerals.

Certain operational aspects of both of these instruments should also be taken into consideration before purchase; each has unique advantages and drawbacks.

The Frantz L-1 model has a few undesirable physical traits. It incorporates a vibrating mechanism and is thus noisy, producing a penetrating and high-pitched sound that is unpleasant and possibly hazardous to the operator. Ideally, this instrument should be kept in its own room, perhaps with other occasional-use apparatus. Care should be exercised in choosing other equipment for the immediate area, however, since the powerful magnetic field created by this unit may adversely affect the performance of computers, among other things. The 150 kg weight of this unit makes it essentially non-portable.

In its mode of operation the Frantz unit has a few flaws. This instrument works best only within a particle range of approximately 125-250 microns diameter, and for optimal results the sample particles should be uniform in size (Allman and Lawrence, 1972). Unfortunately, many micropaleontology samples do not fit this description. Also, a 200 g sample may take two or more hours to feed through, and may require periodic attention from the operator to watch for jamming in the feed hopper. Furthermore, each sample should be microscopically examined beforehand to assess what settings will optimize separation given grain sizes and composition of the fossils, and afterwards may require some hand picking to ensure good representation of fossil types.

In spite of these limitations, this equipment did produce two reasonably good separations from the admittedly difficult samples tested.

The Intermagnetics General Corporation's Magstream Model 100 is also not without problems. Though somewhat quieter than the Frantz unit, it too generates a strong magnetic field, so the same cautions apply to computers and other sensitive equipment. It is smaller than the L-1 and the company describes it as completely portable, although specifications of its weight were not available as of this writing.

One disadvantage of the I.G.C. instrument is that it requires samples to be suspended in Magfluid™ during the actual separation; later the liquid must be rinsed off with water and the sample dried. I.G.C. describes the Magfluid™ as reusable, nontoxic and water soluble (Intermagnetics General Corporation, 1988). As with the L-1, samples should first be examined to determine settings and later to ensure good representation.

Two of the five separations performed with this unit were partially successful, and with some experience on the part of the operator, results could probably improve.

Conclusions

Both these instruments show promise for use in micropaleontological analysis and either one could be of help in routinely concentrating fossils in sediment samples, particularly homogenous outcrop material.

Both have unique advantages and drawbacks, and both require eperienced operators for accurate separation work. Neither machine would totally eliminate the need for hand picking of sample material.

In view of the many differences between the two units, a direct ranking of suitability is not possible; both show promise, both have problems, but either one could be a useful addition to a micropaleontology laboratory.

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REFERENCES

Allman, M. and Lawrence, D.F., 1972. Geological laboratory techniques. Blandford Press, London, U.K., 355p.

Dow, V.E., 1960. Magnetic separation of conodonts. Journal of Paleontology, v.34, p.738-743.

Eckert, R., Hay, W.W., Lorenz, G. and Vogt, P., 1961. The magnetic separator as a tool in micropaleontology. Journal of Paleontology, v.35, p.876-877.

Intermagnetics General Corporation, 1988. How Magstream Works. I.G.C. Magstream™ News, v.1, no.1, p.2. Intermagnetics General Corporation, Guilderland, New York, U.S.A.

Schmidt, R.A.M., 1948. Magnetic separation of microfossils. Journal of Paleontology, v.22, p.530-531.

Thomas, F.C. and Gradstein, F.M., 1981. Tertiary subsurface correlations using pyritized diatoms, offshore Eastern Canada. IN: Current Research, Part B, Geological Survey of Canada, Paper 81-1B, p.17-23.

Thomas, F.C. and Murney, M.G., 1985. Techniques for extraction of foraminifers and ostracodes from sediment samples. Canadian Technical Report of Hydrography and Ocean Sciences, no.54, 24p.

Table 1.
Listing of samples, weights and gross lithologies.

Well	Depth	Weight	Lithology
1. Moheida P-15	8330-8360′	38 g	shale/siltstone/limestone
2. Penobscot B-41	3980-4010′	33 g	mudstone/dolomite
3. Migrant N-20	3380-3410′	6g	chalk/limestone
4. Skolp E-07	2425-2435 m	15 g	silty shale/sandstone
5. Roberval K-62	1265-1275 m	26 g	silty shale

Table 2.
Weights and percentages ( ) of fractions separated by specific gravity and magnetic susceptibility in I.G.C. Magstream Model 100.

Sample	Weight (g)	< 2.50	< 2.63	< 2.90	> 2.90	Loss
1	3.32	1.01 (30.4%)	0.31 (9.3%)	1.43 (43.1%)	0.27 (8.1%)	0.30 (9.1%)
2	2.54	1.18 (46.4%)	0.27 (10.6%)	0.89 (35.0%)	0.18 (7.1%)	0.0 (0.0%)
3	2.47	1.00 (40.5%)	0.38 (15.4%)	0.71 (28.7%)	0.33 (13.4%)	0.05 (2.0%)
4	3.03	0.97 (32.0%)	0.42 (13.9%)	1.03 (34.0%)	0.55 (18.1%)	0.01 (0.3%)
5	3.54	1.23 (34.7%)	0.31 (8.8%)	1.17 (33.0%)	0.41 (11.6%)	0.42 (11.9%)

Table 3.
Weights and percentages ( ) of magnetic and nonmagnetic fractions and total weights of samples separated by the Frantz Isodynamic Magnetic Separator Model L-1.

Sample	Weight (g)	Magnetic	Nonmagnetic
1	n/a	n/a	n/a
2	4.40	3.22 (73.2%)	1.18 (16.8%)
3	1.66	1.31 (78.9%)	0.35 (21.1%)
4	2.60	0.80 (30.1%)	1.80 (69.9%)
5	6.39	0.62 (9.7%)	5.77 (90.3%)

Table 4.
Sample by sample performance of the Frantz L-1 and I.G.C. Magstream 100 separators based on subjective comparison.

Sample	Frantz L-1	I.G.C. Magstream 100
1	n/a	unsuccessful
2	unsuccessful	partially successful
3	unsuccessful	partially successful
4	successful	unsuccessful
5	successful	unsuccessful

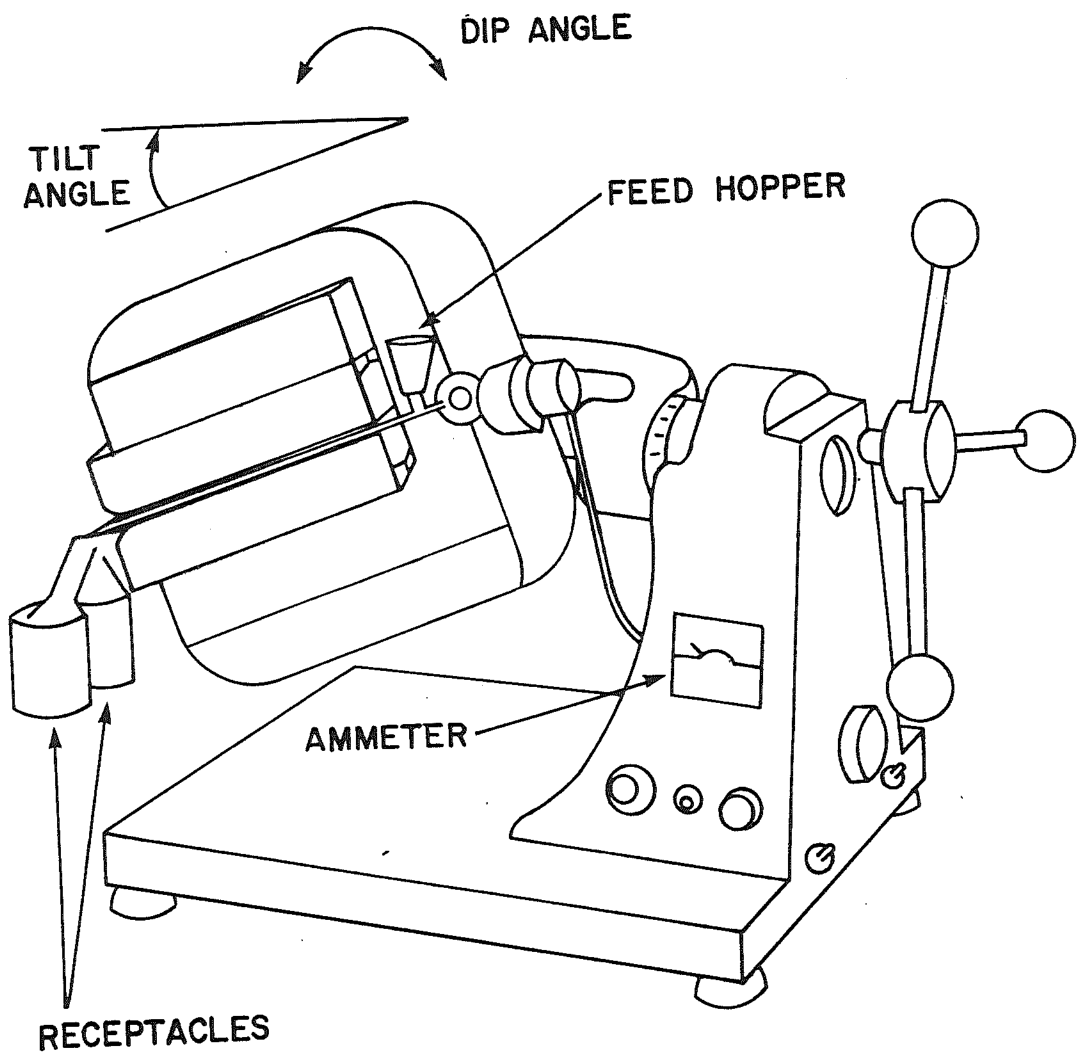

Figure 1 The Frantz Isodynamic Magnetic Separator Model L-1.

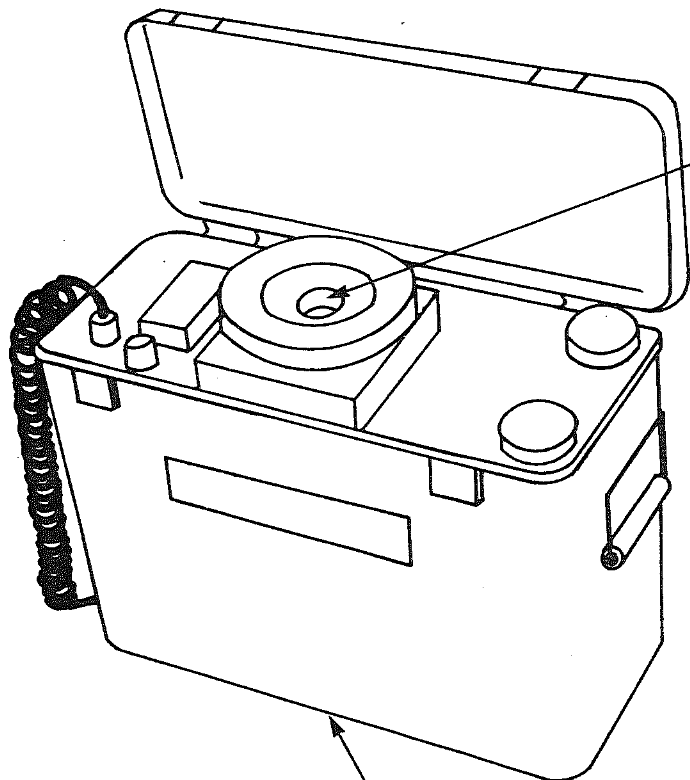

Figure 2 The Intermagnetics General Corporation Magstream™ Model 100 Separator.