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Magnets on Ice

Holocene Paleoclimate Records from the Antarctic Peninsula

Stefanie Brachfeld

IRM

Former IRM lab manager and loess guru Chris Hunt once told me that everyone who comes through the IRM will eventually become involved in a paleoclimatology project. I was interested in secular variation and relative paleointensity records, but at some point during my Ph.D. program I fell in with a bad group of marine geologists. Their field areas along the Antarctic Peninsula displayed intriguing magnetic susceptibility profiles, not to mention breath-taking scenery (figure 1). So began my involvement in Antarctic paleoclimate records, which continues to be the focus of my post-doctoral research. Chris was right after all.

Figure 1. A Gentoo penguin colony on the western Antarctic Peninsula.

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Magnets on the Cob

Studying Paleoclimate in a Cornfield

Christoph Geiss

IRM

I arrived at the *IRM* in March 1994, and, without a project, I spent the next few months playing (and getting acquainted) with all the *IRM*'s fancy instruments. It wasn't until the following August that Subir introduced me to Emi Ito and Herb Wright, who planned to collect lake sediments from Pittsburg Basin in Southern Illinois. Luckily I didn't bring my swim shorts even though the site has been described in the original land survey of 1816 as "*A beautifull lake surrounded a handsome bluff except a small outlet at the NW end ....*" Good ol' American entrepreneurial spirit took care of that, and today Pittsburg Basin is covered by corn and soy with convenient access for a drill truck.

The sediments, on the other hand, were quite worth the effort and the study of their magnetic properties turned into my thesis project. The lake formed at the end of the Illinoian glaciation between gravel ridges of glacio-fluvial origin. Drainage of these ridges and the overlying loess cap is very good, which, combined with very small watersheds, led to very low (for lacustrine environments) sedimentation rates of 10 cm/kyr, and we hoped for a more or less continuous record from the late Illinoian through the Sangamon interglacial, the following Wisconsinan glaciation and into the Holocene. Pollen studies, performed by [*Grüger*, 1972] and, more recently, by [*Teed*, 1999] as part of this study confirm the presence of interglacial plant assemblages throughout the lower part of the core. Unfortunately, the age control for this part of the core (set of eight OSL dates) is too crude to assert the duration of this interglacial period, and at present we are divided about its length.

Mobile hollow stem augur at work at Pittsburg Basin. Jeff Dorale and Jim Neal coring site PBAS 94-5a.

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High-temperature hysteresis, partial TRM, and stepwise LTD in sized magnetite grains (0.6 - 135 µm)

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High-temperature hysteresis. Kosterov (Ph.D. thesis, Montpellier, 1997) reported that saturation remanence, M_{rs}, and coercive force, H_c, of basalts sometimes do not decrease in simple monotonic fashion as the temperature increases, but instead dip sharply and then level out in the range 100-300°C. We have previously observed this phenomenon (Argyle & Dunlop, JGR 95, 7069, 1990; Dunlop, unpublished *IRM* data, 1996, 1998) in both small and large magnetite grains. Kosterov further reported that this dip and plateau disappear if the hysteresis is remeasured in a second heating. His interpretation invokes irreversible changes in local energy minimum (LEM) states during the first heating.

In my visit to the *IRM*, I checked this result and its interpretation by measuring high-temperature hysteresis at 20°C intervals in pairs of successive heatings (and a few triple heatings). I used both unannealed and previously annealed crushed magnetites, covering the size range 0.6 µm to 14 µm (it had been previously found that larger magnetites do not exhibit the phenomenon), as well as two control samples: a natural dark minerals separate from a Precambrian dike (courtesy of B. Zhang) and a sample of hydrothermally recrystallized 3 µm magnetite grains (courtesy of F. Heider). Kosterov's observations were verified in almost all cases.

1. The unannealed magnetites had decided dips and plateaus in M_{rs} and H_c in the first heating (particularly the 6 µm, 9 µm and 14 µm grains). There were no such irregularities in the second or third heatings.
2. Previously annealed magnetites had no dips and plateaus. Their results matched those of the second heatings of the unannealed magnetites of similar size.
3. The dark minerals separate, which cooled slowly from the melt in nature, has only a very muted dip and plateau, which is similar in both first and second heatings.
4. The hydrothermal magnetite behaves quite differently. In its first heating, M_{rs} and H_c *increase* by about 20% between 50 and 100°C, then drop gradually back to expected levels by 250°C. In the second heating, the patterns are simple and monotonic, as with other samples.

The results demonstrate that samples can change their internal states quite dramatically at relatively low temperatures during a first heating. Hysteresis parameters in a second heating are often quite different and are reproducible in subsequent heatings. Samples that have thermally equilibrated in nature or in prior annealing give more trustworthy first-heating hysteresis data. The cause of the dip and plateau in crushed grains seems more likely to be related to annealing out of internal stress or changes in particle morphology than to changes in LEM state because the coercive force invariably drops, suggesting a decrease in internal stress.

Partial TRM. I extended the additivity of partial TRM experiments for 125-150 µm magnetites described in the *IRM* Quarterly, vol.8, no.4 by measuring the vector sums of neighbouring pTRM's produced in perpendicular fields and in anti-parallel fields. Previously all pTRM's were produced in the conventional manner in parallel fields, but in nature, secondary pTRM's are frequently overprinted at large angles or following a field reversal. There is no *a priori* reason for expecting domain structures in large crystals to behave in a simple way when the field is changed through a large angle, but rather surprisingly, vector additivity of partial TRM's was experimentally verified to within 5% in all cases, and often to within 1%.

I also tested whether additivity of parallel pTRM's depends on the applied field for two different values of T_i, 300°C and 500°C. The field values tested were 2, 3, 5, 7 and 10 Oe. Additivity was verified in all cases, with no obvious pattern. The deviations from perfect additivity were sometimes positive (sum of pTRM's > total TRM) and sometimes negative, and varied from 0.1% to 7.1%. In all but one case the deviations were <3.5%.

The fact that pTRM's are additive for large multidomain grains does not imply that these partial TRM's behave in single-domain-like fashion in other respects. The laws of independence and reciprocity are violated (IUGG, Birmingham, 1999).

Stepwise low-temperature demagnetization (LTD). I measured detailed (every 2 K) zero-field cooling and heating curves for SIRM imparted at

Test of additivity of perpendicular pTRM's

H (Oe)	T_i (°C)	pTRM (T_c,T_i)	pTRM (T_i,T_o)	Vector sum	Measured composite
3, 5	300	7.07	2.98	7.67	7.69
3, 5	400	6.72	3.48	7.57	7.54
3, 5	500	6.08	4.14	7.35	7.37

Test of additivity of anti-parallel pTRM's

H (Oe)	T_i (°C)	pTRM (T_c,T_i)	pTRM (T_i,T_o)	Vector sum	Measured composite
5	300	11.00	3.03	7.97	7.61
3	400	6.72	1.95	4.77	4.58
3	500	6.08	2.69	3.39	3.33
5	500	9.10	4.14	4.96	4.89
3	564	5.05	4.64	0.41	-0.44

room temperature, proceeding in steps: cycling to 200 K and back to R.T., then to 150 K, 130 K, 120 K, 110 K, and finally 100 K, returning each time to R.T. This experiment was carried out for crushed and annealed magnetites of many different sizes with similar results:

1. There is a small reversible recovery of remanence in the heating half of each cycle, with a matching loss in the cooling half of the next cycle. For example, after cooling to 150 K, most of the loss of SIRM is permanent, but perhaps 10% is recovered in reheating to R.T. This same 10% is again lost in the second cooling to 150 K, and cooling below 130 K results in further irreversible loss, with a quite different dM/dT. The thermal cycles thus resemble minor loops in hysteresis cycling.
2. Also just as the major hysteresis loop is the envelope of all minor loops, the one-step cooling and rewarming curve from R.T. to 100 K and back to R.T. is the exact envelope of the set of stepwise cycles to intermediate temperatures.
3. These results, although preliminary, seem to establish stepwise LTD as a potential practical paleomagnetic cleaning method. It is analogous to stepwise AF demagnetization and even more directly analogous to stepwise thermal demagnetization, except that chemically non-destructive cooling is involved instead of heating.

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Testing For Magnetosomes In Lake Ely Sediments

The objective of our *IRM* measurements was to test the possibility that variations in the amount of biogenic magnetite has caused the observed SIRM variations in recent lake sediments from Lake Ely in northeastern Pennsylvania. We used Moskowitz et al.'s (1993) ratio of low temperature SIRMs after cooling in a field or in a zero field (FC/ZFC) measured in the MPMS to quantify the amount of biogenic magnetite. We were interested in biogenic magnetite since it appears that the SIRM variations downcore in Lake Ely sediments correlate with local rainfall over the past 60 years, the length of the local rainfall record. High SIRM samples have more dark, organic-rich mud and low SIRM samples have more light-colored silt. The high SIRM samples appear to correlate with greater rainfall, the silt-rich layers with lower rainfall, thus this is opposite to the expected relationship for an erosional model. The hypothesis we tested suggests that more rainfall stimulated more biologic production in the lake and hence more biogenic magnetite would be created.

The FC and ZFC curves showed the presence of a Verwey transition indicating magnetite, but they also (along with the room temperature SIRM curves (RTSIRM)) showed the presence of a second phase which made the use of Moskowitz et al.'s technique difficult. The room temperature SIRM cooling and heating curves made a characteristic "grebe" head shape probably due to the presence of the second phase. Subir Banerjee and Mike Jackson have suggested to me that their experience indicates that this type of low temperature behavior is probably due to the presence of a small amount of magnetite with a larger amount of goethite.

Unfortunately, the FC/ZFC ratios could not distinguish between the high and low SIRM samples at Lake Ely. All samples had FC/ZFC ratios near to 1.5. Based on Moskowitz et al.'s (1993) binary mixing model this would suggest about 60% biogenic magnetite. The FC/ZFC ratios did show that before settlement of the lake watershed the FC/ZFC ratios were significantly lower (1.2) suggesting only 10% biogenic magnetite. Since the watershed had not been disturbed and the high S ratios of the pre-settlement samples indicate that very little catchment soils are being eroded into the lake at this time, this would suggest chemical rather than biologic production of magnetite in the lake. It could also mean that the chains of biogenic magnetite were no longer intact.

Hysteresis parameters from Lake Ely sediments show that post-settlement samples have magnetite in the PSD grain-size range, but that the pre-settlement sample had much finer magnetic particles, closer to the SD range. This is supported by a higher SIRM/χ ratio for the pre-settlement sample (3.8) than for the post-settlement samples (2.2-3.0). These ratios suggest that greigite is not an important magnetic mineral in this lake. Saturation magnetization versus temperature measurements (J_{sat}-T) show a prominent bulge in the heating curve of post-settlement samples between 400°C and 550°C and a Curie point of about 580°C. The curve is irreversible and builds to a value of about 4-5 times the starting saturation magnetization. The pre-settlement sample does not show this bulge but does show a 580°C Curie point. The J_{sat}-T results seem to suggest the growth of a strong magnetic phase above 400°C. This could be goethite converting to magnetite caused by heating of these organic-rich samples. The pre-settlement sample apparently doesn't have much goethite. This is supported by less contamination of this sample's FC, ZFC, and RTSIRM curves by a second phase.

The MPMS measurements made at *IRM* do not appear to support a biogenic cause for the SIRM variations observed in Lake Ely sediments. The *IRM* measurements do show that the predominant pre-settlement magnetic mineral is fine-grained (nearly SD) magnetite which is not biogenic. The post-settlement samples that apparently record rainfall variations contain a mixture of goethite and PSD magnetite. About 60% of the magnetite appears to be biogenic. Unfortunately the presence of the second magnetic phase in the rocks (goethite?) makes use of the Moskowitz et al. technique for detecting biogenic magnetite difficult. We will attempt other ways of detecting the presence biogenic magnetite in pre-settlement and post-settlement lake sediments.

Samples from Lake Waynewood, also in northeastern Pennsylvania, were measured on the MPMS to see if FC/ZFC ratios were different for high and low intensity SIRMs that appear to correlate with regional rainfall variations. Again the FC/ZFC ratios showed no distinction between the samples; however, a second magnetic phase was also present. From the "grebe"-shaped RTSIRM curves it is probably goethite. J_{sat}-T curves also show the growth of a highly magnetic phase above 400°C. Magnetic grain sizes are in the PSD grain size range.

I enjoyed my stay at the *IRM* very much. Although the MPMS measurements did not support my hypothesis, this result has inspired me to look at the data with a fresh perspective. I would also like to see if biogenic magnetite can be detected in these sediments in other ways (direct observation, for example), to get a feeling for the sensitivity of the FC/ZFC method when more than one magnetic phase is present.

Moskowitz, B.M., R. Frankel, and D. Bazylinski, Rock magnetic criteria for the detection of biogenic magnetite, *Earth and Planetary Science Letters*, *120*, 283–300, 1993.

Visiting Fellow Reports
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Low-Temperature Remanence In Single Crystals Of Titanomagnetites

On my visit to the *IRM*, I had natural single crystals of titanomagnetites, extracted from dacite tuff of Mt. Haruna, Japan. The octahedral crystals are about 0.2 and 0.4 mm on edge. High-field thermomagnetic curves were measured on the micro-VSM. The Curie temperatures of the crystals are between 450 and 470 C, indicating composition near TM15-TM18 (Akimoto, 1962). However, impurities such as Al^{3+} or Mg^{2+} in the crystals would affect the composition. The hysteresis curves have ramp-like shapes with coercive forces of 0.4-1 mT and saturation remanence ratios of 0.003 - 0.006. These low values of Hc and Mrs/Ms indicate true multidomain behaviour.

Low-temperature remanence measurement were made with an MPMS2 magnetometer with a SQUID detector. The crystals were given a saturation isothermal remanent magnetization in a field of 2.5 T at 20 K, then warmed to 300 K in approximately zero field. SIRM decreased rapidly between 20 K and 50 K. At 50 K, 80% of the original SIRM had been destroyed. The shape of the SIRM demagnetization curve is very similar to that of titanomagnetite of composition x=0.19 as reported by Moskowitz at al.(1998). However, the remanence transition takes place at slightly lower temperature.

The crystals were given a new SIRM in a field of 2.5 T at room temperature, then cooled to 20 K and back to 300 K in zero field. The remanence decreased steadily with cooling to 50 K, at which 80 % of the initial SIRM had been demagnetized. In further cooling below 50 K, the remanence remained essentially constant. As the crystal was warmed from 20 K, the SIRM retraced the cooling curve in the range 20-50K. Warming above 50 K resulted in an gradual increase in remanence. At room temperature, almost 45 % of the initial remanence was recovered. The second crystal changed its SIRM in the same way with a higher memory ratio of 60%.

The sharp decrease in SIRM warming and a gradual increase in SIRM cooling curves around 50 K perhaps indicates the magnetic isotropic point where the first magnetocrystalline anisotropy constant becomes zero and changes its sign. The surprising result of my study is that a 0.3 mm crystal of titanomagnetite , with all the hallmarks of truly MD hysteresis behaviour shows a high SIRM memory.

Moskowitz, B.M., M. Jackson, and C. Kissel, Low-temperature magnetic behavior of titanomagnetites, *Earth and Planetary Science Letters*, *157* (3-4), 141-9, 1998.

New Visiting Fellows

Congratulations to the new group of *IRM* Visiting Fellows, who will carry out their research during the fall and winter. Once again, the competition was very strong, with a large number of very good proposals. Those selected by the *IRM*'s Review and Advisory Committee are:

Franz Heider, *GeoForschungsZentrum Potsdam*, Magnetic Force Microscopy of exsolved titanomagnetites

Christoph Heunemann, *Ludwig-Maximilians-Universitat Munchen*, Magnetic properties of tissue containing superparamagnetic magnetite

William Johnson, *University of Kansas*, Rock magnetic study of loess-paleosol sequences in the central Great Plains

Gunther Kletetschka, *NASA-GSFC*, Why does MD hematite acquire such a large magnetization when cooling through its Curie temperature in the geomagnetic field?

Andrei Kosterov, *Geological Survey of Japan*, Magnetic hysteresis of basaltic rocks and synthetic magnetites at very low temperatures

Arlo Weil, *University of Michigan*, SEM and rock-magnetic study of two Devonian limestone formations from the Cantabria-Asturias Arc, northern Spain

Yong Jae Yu, *University of Toronto*, Thermal variations of hysteresis properties for hemoilmenite grains.

Fifth Santa Fe Conference

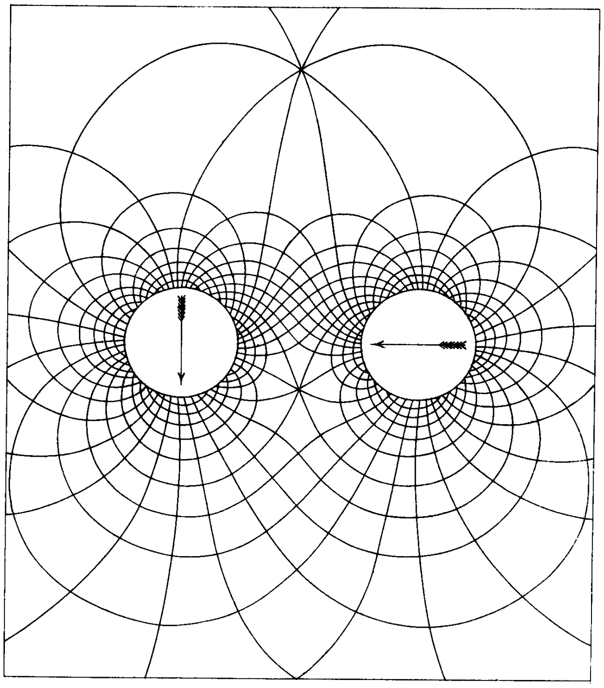
We are pleased to announce that plans are now being made for the Fifth Santa Fe Conference on Rock Magnetism. The venue will again be St. John's College, which previous meetings have proven to be an ideal setting for informal, in-depth, insightful discussions. Mark your calendars: July 20-23, 2000.

We welcome your suggestions for one or more focus areas or conference themes. Previous meetings have zeroed in on:

"Rock Magnetism and Chemical Change: the Signal and Noise in the Paleomagnetic Record" (1992)
"Remagnetization and Environmental Rock Magnetism" (1994)
"Very-High-Resolution (VHR) Recording of Paleomagnetic Field and Paleoclimate Variations" (1996)
"Geodynamo and Environmental Change: Interpreting Paleorecords through Rock Magnetism" (1998).

Guided by previous successful Santa Fe experiences, we will conduct the meeting in an open, discussion-oriented format, with about 40 or 45 participants, and a small number of invited talks to get the ball rolling. We welcome the participation of students, post-docs and veteran researchers. As in the past Santa Fe conferences, we hope to be able to provide partial reimbursement of travel expenses, pending funding by NSF.

FIG. XIV.
Art. 388.



Two Cylinders magnetized transversely.

From ***A Treatise on Electricity and Magnetism****, by James Clerk Maxwell. Third edition, Dover Publishing.*

Current Abstracts

A list of current research articles dealing with various topics in the physics and chemistry of magnetism is a regular feature of the IRM Quarterly*. Articles published in familiar geology and geophysics journals are included; special emphasis is given to current articles from physics, chemistry, and materials-science journals. Most abstracts are culled from* INSPEC *(© Institution of Electrical Engineers),* Geophysical Abstracts in Press *(© American Geophysical Union), and* The Earth and Planetary Express *(© Elsevier Science Publishers, B.V.), after which they are subjected to Procrustean editing and condensation for this newsletter. An extensive reference list of articles (primarily about rock magnetism, the physics and chemistry of magnetism, and some paleomagnetism) is continually updated at the* IRM*. This list, with more than 4200 references, is available free of charge. Your contributions both to the list and to the Abstracts section of the* IRM Quarterly *are always welcome.*

Biogeomagnetism

Gibbs-Eggar, Z., Jude, B., Dominik, J., Loizeau, J. L., and Oldfield, F., 1999, **Possible evidence for dissimilatory bacterial magnetite dominating the magnetic properties of recent lake sediments**: *Earth and Planetary Science Letters, v. 168*, no. 1-2, p. 1-6.
Rock magnetic measurements show that the most recent sediments from the Bay of Vidy, Lake Geneva are rich in superparamagnetic magnetite. The ^{137}Cs-dated increase in magnetite concentration coincides with the beginning of sewage de-phosphatization by the addition of iron chloride. Extracts imaged by TEM form amorphous masses comparable to extracellular bacterial magnetite. This is the first indication that extracellular, dissimilatory magnetite may survive and make a dominant contribution to the magnetic properties of sediments. Final confirmation of the bacterial origin of the magnetite will depend on rRNA sequencing.

Extraterrestrial Magnetism

Madsen, M. B., Hviid, S. F., Gunnlaugsson, H. P., Knudsen, J. M., Goetz, W., Pendersen, C. T., Dinesesn, A. R., Mogensen, C. T., Olsen, M., and Hargraves, R. B., 1999, **The magnetic properties experiments on Mars Pathfinder**: *Journal of Geophysical Research, v. 104*, no. E4, p. 8761-79.
Dust suspended in the Martian atmosphere is not solely single-phase hematite (α- Fe_2O_3), and single-phase particles of maghemite (γ-Fe_2O_3) or magnetite (Fe_3O_4) are not present in any appreciable amount. The particles in the airborne dust seem to be composite, containing a few percent of a strongly magnetic component, most likely maghemite, as stain and cement. These results imply that Fe^{2+} ions were leached from the bedrock, and after passing through a state as free Fe^{2+} ions in liquid water, the Fe^{2+} was oxidized to Fe^{3+} and then precipitated. It cannot, however, be ruled out that the magnetic particles are titanomagnetite (or titanomaghemite) occurring in palagonite, having been inherited directly from the bedrock.

Withey, P. A., and Nuth, J. A., III, 1999, **Formation of single-magnetic-domain iron particles via vapor-phase nucleation: implications for the Solar Nebula**: *Icarus, v. 139*, no. 2, p. 367-73.
Experiments indicate production of single-magnetic-domain iron grains via vapor-phase nucleation even in the absence of an ambient magnetic field. These single domain grains are thermodynamically stable as saturated magnetic dipoles. The spontaneous formation of single-domain iron grains, and by inference a variety of other single-domain particles such as taenite or magnetite, could greatly increase the coagulation efficiency of submicrometer-sized grains in the primitive Solar Nebula. An important test of this hypothesis is proposed: an examination of 20- to 50-nm diameter iron grains in the matrix of very primitive chondrites should reveal an interconnected, three-dimensional string or web-like structure within the matrix.

Magnetic Microscopy and Spectroscopy

Hagiwara, K., Kanazawa, M., Horie, K., Kokubun, J., and Ishida, K., 1999, **Measurements of ATS scattering from magnetite near the Fe K-absorption edge in the temperature range 290 K-80 K**: *Journal of the Physical Society of Japan, v. 68*, no. 5, p. 1592-7.
X-ray resonant scattering, due to the anisotropic tensor of susceptibility (ATS), from magnetite, Fe_3O_4, near the Fe K-absorption edge, was measured from room temperature to 80 K. The energy dependence of the 002 "forbidden" reflection intensity showed two sharp peaks just above and below the edge. The azimuthal dependence of both peaks was well described by an anisotropic second rank tensor of an iron atom at the B-site (octahedral site) of the spinel lattice. The energy dependence of the reflection at 80 K was almost the same as that at room temperature except for an additional intensity enhancement due to the structural transition.

Menon, N. K., and Yuan, J., 1999, **Towards atomic resolution EELS of anisotropic materials**: *Ultramicroscopy, v. 78*, no. 1-4, p. 185-205.
We present a scheme for the analysis of electron energy-loss spectra of materials with magnetic or crystalline anisotropy. The two components of the dielectric function in the antiferromagnetic compound hematite (α-Fe_2O_3) are extracted from two spectra acquired with different convergence angles. From the resulting difference spectrum, the orientation of the Fe magnetic moments is deduced to be perpendicular to the trigonal axis in this crystal. This success opens the way for the study of anisotropic electronic structure at high spatial resolution-an example would be the imaging of changes in spin orientation at domain walls.

Magnetism of the Seafloor

Gee, J., and Kent, D. V., 1999, **Calibration of magnetic granulometric trends in oceanic basalts**: *Earth and Planetary Science Letters, v. 170*, no. 4, p. 377-90.
Hysteresis data show local and long-term temporal trends in magnetic grain size of mid-ocean ridge basalts spanning a range of ages from 0 to 122 Ma. Specimens systematically taken along transects perpendicular to the chilled margin of each sample show progressive changes on approaching the chilled margin, allowing recognition of mixing trends between MD and SD grains and between SD and SP grains. These trends in hysteresis parameters are crucial to resolving the inherent, but frequently overlooked, ambiguity in inferring grain size from hysteresis parameters.

Hall, J. M., and Muzzatti, A., 1999, **Delayed magnetization of the deeper kilometer of oceanic crust at Ocean Drilling Project Site 504**: *Journal of Geophysical Research, v. 104*, no. B6, p. 12843-51.
The Fe-Ti magnetic carriers of the dike-rich second kilometer of oceanic crust at Ocean Drilling Program Site 504 are shown to be

secondary in origin. An important consequence of the delay in formation of carriers is that the polarity of their magnetization has a significant probability of opposing that of the overlying, little-altered extrusives. Two types of secondary magnetite are recognized in the dikes of the second kilometer of the crust at Site 504. Both were formed in conditions of hydrothermal greenschist metamorphism.

Horen, H., and Fleutelot, C., 1998, **Highly magnetised and differentiated basalts at the 18-19°S propagating spreading centre in the North Fiji Basin**: *Marine Geophysical Researches, v. 20*, no. 2, p. 129-37.
Two phenomena appear to be important in controlling variations of natural remanent magnetisation (NRM) along a propagating spreading centre: (1) intensity of NRM and extensive magma differentiation to Fe-Ti basalts both increase towards the propagator tip, (2) low temperature oxidation (maghemitisation) seems to have already occurred along the ridge axis for the zero age basalts. Despite the apparent lack of correlation between NRM and maghemitisation (masked by the effect of extensive magma differentiation), the latter involves a change of the domain state of magnetic carriers, from PSD to single-domain. Despite the relatively high degree of maghemitisation, the variations of NRM intensity principally reflect the variations of magmatic processes.

Paleoclimate and Environmental Magnetism

Hanesch, M., and Petersen, N., 1999, **Magnetic properties of a recent parabrown-earth from Southern Germany**: *Earth and Planetary Science Letters, v. 169*, no. 1-2, p. 85-97.
A vertical soil structure defined by magnetic measurements (susceptibility, isothermal remanence, ratio of anhysteretic to isothermal remanence, various hysteresis parameters and viscous remanence) reveals details not seen in the general pedological horizons. Magnetic properties in the topsoil were influenced by the former cultivation of the soil and by the presence of a remarkable amount of strongly magnetic industrial fly ash. In the underlying horizons pedogenically formed ferrimagnetic minerals dominate the magnetic properties. This material forms only in the presence of iron-reducing bacteria. Transmission electron microscopy showed that these magnetite particles have an average grain size of 5 nm; they probably form clusters as the magnetic properties rather indicate particles that are at the boundary between superparamagnetic and single domain behaviour.

Lanci, L., Hirt, A. M., Lowrie, W., Lotter, A. F., Lemcke, G., and Sturm, M., 1999, **Mineral-magnetic record of late Quaternary climatic changes in a high alpine lake**: *Earth and Planetary Science Letters, v. 170*, no. 1-2, p. 49-59.
Pollen data show that these sediments extend from the present to the Younger Dryas. The climatic warming of the early Holocene is marked by near-disappearance of the high-coercivity magnetic minerals, a sharp increase in the concentration of ferrimagnetic minerals and a decrease in the contribution of superparamagnetic grains. Similar variations, of smaller magnitude, are found in the Holocene and are interpreted to represent minor climatic variations. Comparison with the historical record of the last 1000 years confirms this interpretation. The coarse-grained, late-glacial sediments have magnetic propoerties similar to those measured in the catchment bedrock. This indicates a detrital origin. The different properties and the higher concentration of magnetic minerals in the Holocene sediments are due to authigenic phases.

Xiu Ming, L., Hesse, P., and Rolph, T., 1999, **Origin of maghaemite in Chinese loess deposits: aeolian or pedogenic?**: *Physics of the Earth and Planetary Interiors, v. 112*, no. 3-4, p. 191-201.
Maghaemite and magnetite, common ferrimagnetic minerals in surficial soils, have physical properties which are similar except for the thermal instability of the former. Thermomagnetic properties has been used to systematically separate these two magnetic components in loess and palaeosol samples from the upper parts of the Luochuan section. Although maghaemite (thermally unstable component) occurs in greater amounts in palaeosols (M_S=0.0187 $Am^2\ kg^{-1}$±1.1%) than in loess units (M_S=0.0156 $Am^2\ kg^{-1}$±1.1%), in relative terms its contribution to the ferrimagnetic component of magnetisation is higher in the loess units (ΔM_S(%)=32.2±2.0) than the soils (ΔM_S(%)=23.5±3.7). Such an observation suggests that much of the maghaemite component originates in the aeolian source area, with some addition of pedogenic maghaemite occurring in the palaeosols.

Remanence and Magnetization Processes

Bina, M., Tanguy, J. C., Hoffmann, V., Prevot, M., Listanco, E. L., Keller, R., Fehr, K. T., Goguitchaichvili, A. T., and Punongbayan, R. S., 1999, **A detailed magnetic and mineralogical study of self-reversed dacitic pumices from the 1991 Pinatubo eruption (Philippines)**: *Geophysical Journal International, v. 138*, no. 1, p. 159-78.
Thirty-nine dacitic pumice and lithic samples from the 1991 eruption of Mount Pinatubo were investigated through both magnetic and mineralogical means. Natural remanent magnetization (NRM) is found to be reversed for most of the samples, with respect to the direction of the actual geomagnetic field direction. A few samples, amongst them ancient lithics transported by pyroclastic flows, show scattered NRM directions. From thermal demagnetization of these particular samples it is concluded that their orientation changed after emplacement. The emplacement temperature is estimated to be more than 460°C from thermal demagnetization of lithic samples.

Kok, Y. S., and Tauxe, L., 1999, **Long-τ VRM and relative paleointensity estimates in sediments**: *Earth and Planetary Science Letters, v. 168*, no. 1-2, p. 145-58.
A new method for quantifying long-term VRM (and its effect on sedimentary paleointensities) uses the typically nonlinear relationship between artificial magnetization acquired and NRM demagnetized in a set of steps. Although these nonlinear parts are to be avoided for paleointensity determinations, they are effective indicators of long-relaxation time VRM. The method, which does not require determining paleointensity values, suggests correlations with paleoclimate curves and age-dependent growth of VRM.

Shi, H., and Tarling, D. H., 1999, **The origin of bore-core remanences: mechanical-shock-imposed irreversible magnetizations**: *Geophysical Journal International, v. 137*, no. 3, p. 831-8.
Repeated laboratory-induced weak mechanical shocking (c. 0.57 kg m s^{-1}) of marine sandstone samples showing drilling-induced remanence causes increases in their low-field susceptibility (χ) and their ability to acquire an isothermal remanent magnetization (IRM). Differences in the magnetic mineralogy of shocked and unshocked marine samples suggest that the magnetic enhancement is predominantly due to the creation of pyrrhotite by shock-induced irreversible crystallographic changes in iron-bearing sulphides.

Synthesis and Properties of Magnetic Minerals

Brabers, J. H. V. J., Walz, F., and Kronmuller, H., 1999, **A model for the Verwey transition based on an effective interionic potential**: *Physica B, v. 266*, no. 4, p. 321-31.
A model for the Verwey transition has been developed and tested against experimental data. A mean field analysis, in which the experimentally determined value of the energy gap between the octahedral 2+ and 3+-levels serves as an input parameter, reproduces the observed value of the Verwey transition of 125 K quite well, thereby indicating dominant long range interactions. These long range interactions are most likely Coulomb-type interactions. The strong effect of cation substitutions on the Verwey transition can be explained quantitatively on the basis of interionic Coulomb interactions and balancing of the local charge distribution.

Brabers, J. H. V. J., Walz, F., and Kronmuller, H., 1999, **The role of volume effects in the Verwey transition in magnetite**: *Journal of Physics: Condensed Matter, v. 11*, no. 18, p. 3679-86.
Fe^{2+}/Fe^{3+} ordering in magnetite is described in terms of a simple mean-field approach based on an effective interionic Coulomb potential. First-order electronic order-disorder transformations, as reported in the literature, can only be reproduced when the dependence of the interionic potential on the unit-cell dimensions is taken into account. In this case the first-order transitions can then be viewed as the result of an interplay between the lattice-deformation energy and the free-energy contribution related to the electronic ordering of the octahedral Fe lattice. Furthermore, the effect of the lattice deformation by hydrostatic pressure on the Verwey transition can be successfully explained to some extent within the same framework.

Brown, A. P., and O'Reilly, W., 1999, **Magnetic properties of pulverized titanomagnetite, $Fe_{2.4}Ti_{0.6}O_4$: effect of thermal fluctuations**: *Geophysical Journal International, v. 138*, no. 1, p. 199-204.
The magnetic properties of titanomagnetite, $Fe_{2.4}Ti_{0.6}O_4$, pulverized in a ball mill for times between 3.5 and 78 hr form a consistent picture if the material is treated as monodomain particles of decreasing size progressively subject to thermal fluctuations. The magnetic observations are made over a range of characteristic measurement times: 10^{-3} s (susceptibility measurement), 1 s (coercive force measurement) and 10^4 s (viscous decay of remanence). The magnetic viscosity coefficient first rises then falls as pulverization proceeds. The application of a field equal to the coercive force shifts the distribution so that the peak corresponds to the characteristic time of the coercive force measurement. At maximum pulverization time, the peak in the zero-field time-constant distribution is five orders of magnitude bigger than the characteristic time of susceptibility measurement, which can be satisfactorily interpreted in terms of only a few per cent of the particle assemblage being affected by thermal fluctuations.

Dimitrov, D. V., Unruh, K., Hadjipanayis, G. C., Papaefthymiou, V., and Simopoulos, A., 1999, **Ferrimagnetism and defect clusters in $Fe_{1-x}O$ films**: *Physical Review B, v. 59*, no. 22, p. 14499-504.
Nonstoichiometric single phase $Fe_{1-x}O$ films with ferrimagnetic properties, large saturation magnetization (M_s), and low-temperature coercivity (H_c) have been prepared and studied. A model based on the existence of 16:5 spinel-type defect clusters predicts a linear dependence between M_s and the lattice parameter (a). The experimental data of M_s versus a is a straight line passing through the point (Ms,a) of bulk Fe_3O_4 . This fact suggests that $Fe_{1-x}O$ is the link between the two phases Fe_3O_4 and FeO, which have seemingly different physical nature and properties, into one class of materials.

Iakovenko, S. A., Trifonov, A. S., Giersig, M., Mamedov, A., Nagesha, D. K., Hanin, V. V., Soldatov, E. C., and Kotov, N. A., 1999, **One- and two-dimensional arrays of magnetic nanoparticles by the Langmuir-Blodgett technique**: *Advanced Materials, v. 11*, no. 5, p. 388-92.
Well-ordered arrays of Fe_3O_4 nanoparticles with a new type of packing have been produced using the Langmuir-Blodgett technique. Depending on the local absorption conditions, both 2D and 1D assemblies of nanoparticles are produced, the latter in the form of single and double chains of equally spaced nano-particles.

Kitamoto, Y., and Abe, M., 1999, **Nanostructured oxide films by ferrite plating with sonochemistry**: *Nanostructured Materials, v. 12*, p. 1-4.
By applying power ultrasound waves to $FeCl_2$ aqueous solution at 70°C, we successfully encapsulated polyacrylate spheres of 250 nm in average diameter with magnetite ferrite coatings. This broke the previous lower limit (300 nm) of the size of the particles to be encapsulated; without application of the ultrasound waves, the ferrite coating became discontinuous or insular. The ultrasound waves produce on the polymer surfaces OH groups, which work as ferrite nucleation sites. The ferrite-encapsulated particles will greatly improve the performance of the enzyme immunoassay as a cancer test reagent.

Kominami, H., Onoue, S., Matsuo, K., and Kera, Y., 1999, **Synthesis of microcrystal-line hematite and magnetite in organic solvents and effect of a small amount of water in the solvents**: *Journal of the American Ceramic Society, v. 82*, no. 7, p. 1937-40.
Microcrystalline magnetite (Fe_3O_4) particles having diameters of 7-34 nm were synthesized by thermal treatment of iron(III) acetylacetonate in organic solvents at high temperatures (423-573 K). When the treatment was conducted in 1-propanol containing a small amount of water (1-3 vol%), nanosized hematite (α- Fe_2O_3) crystallized, which then was reduced to magnetite after a prolonged reaction time.

Li, J., Liu, C., Zhao, B., Lin, Y., and Deng, Z., 1999, **Structures and properties of Fe-C fine particles prepared by AC arc discharge**: *Journal of Magnetism and Magnetic Materials, v. 195*, no. 2, p. 470-5.
Fe-C fine particles are produced by an alternating arc discharge between iron and carbon electrodes in an Ar gas atmosphere at pressures of 8, 14 and 18 kPa. The particles are of two different crystal structures: hexagonal FeC and cubic iron. The iron particles have a multi-layered structure composed of an α-Fe core wrapped by Fe_3O_4 , FeO and FeO(OH) shells. It is found that the compositions and the specific saturation magnetization of the Fe-C particles prepared in different pressures of Ar gas are not the same, but their Curie temperatures are all 580±5°C.

Miyake, S., Kinomura, N., Suzuki, T., and Suwa, T., 1999, **Fabrication of spherical magnetite particles by the flame fusion method**: *Journal of Materials Science, v. 34*, no. 12, p. 2921-8.
Fabrication of spherical magnetite powders was investigated in the propane-oxygen flame using sponge iron powders as a starting powder. Spherical particles produced by fusion, sphering and oxidation of iron powder were composed of residual Fe, FeO, Fe_3O_4 and α- Fe_2O_3 in the case of particles collected by a cyclone. The amount of Fe_3O_4 in the products was strongly dependent on the propane/ oxygen ratio and the flow rate of carrier air, but weakly on the feed rate of iron powder. Injection of quenching gas was found to be effective to improve the yield of Fe_3O_4 . The particle size of products reflected directly that of starting powders, indicating fairly easy control of particle size of products.

Muxworthy, A. R., 1999, **Low-temperature susceptibility and hysteresis of magnetite**: *Earth and Planetary Science Letters, v. 169*, no. 1-2, p. 51-8.
Large multidomain hydrothermal magnetite samples display frequency-dependent anomalies in susceptibility χ across the Verwey transition (T_v≈120K), and also at 50 K, attributed to discontinuities in the hopping frequency of electrons. The coercive force (H_c) displays a sharp discontinuity at the magnetocrystalline anisotropy isotropic point (T_k). The difference in low-temperature behaviour of 'high-field' parameters, e.g., H_c at T_k, and 'low-field' parameters, e.g., χ at T_v, is due to the partial destruction, in high fields, of the Vonsovskii exchange interaction, the mechanism by which electronic ordering occurs at T_v according the magneto-electronic model of the Verwey transition.

O'Connor, C. J., Seip, C. T., Carpenter, E. E., Sichu, L., and John, V. T., 1999, **Synthesis and reactivity of nanophase ferrites in reverse micellar solutions**: *Nanostructured Materials, v. 12*, p. 1-4.
Synthesis of magnetic nanoparticles using surfactant systems such as water-in-oil microemulsions (reverse micelles) provides excellent control over particle size, inter-particle spacing, and particle shape. These environments have been used in the synthesis of γ- Fe_2O_3 , Fe_3O_4 , $MnFe_2O_4$, and $CoFe_2O_4$ with particle sizes ranging from 10-20 nm. The controlled environment of the reverse micelle also allows sequential synthesis which can produce a core-shell type structure, for example Fe_3O_4 nanoparticles with MnO coatings. Lyotropic liquid crystal media also offer template effects for the synthesis of magnetic nanostructures.

Skumryev, V., Blythe, H. J., Cullen, J., and Coey, J. M. D., 1999, **AC susceptibility of a magnetite crystal**: *Journal of Magnetism and Magnetic Materials, v. 196*, no. S0304, p. 00863-4.
The AC susceptibility of an Fe_3O_4 crystal has been studied from 4.2 to 300 K with field applied along a [110] direction. There is a sharp peak in χ' and minimum in χ" at 130 K where K1 changes sign, a precipitous drop in χ' and maximum in χ" at the Verwey transition and a further, frequency-dependent decrease in χ' accompanied by peak in χ" below 50 K. The low-temperature behavior is associated with an activated relaxation process having τ_0=6*10^{-9} s, E_a=0.04 eV which is due to the coupled electron hopping and domain wall motion.

Zdujic, M., Jovalekic, C., Karanovic, L., and Mitric, M., 1999, **The ball milling induced transformation of α-Fe_2O_3 powder in air and oxygen atmosphere**: *Materials Science & Engineering A, v. A262*, no. 1-2, p. 204-13.
Under appropriate milling conditions, α-Fe_2O_3 completely transforms to Fe_3O_4, and for prolonged milling to the $Fe_{1-x}O$ phase, either in air or oxygen atmosphere. The reverse mechanochemical reaction $Fe_{1-x}O$ to Fe_3O_4 to α-Fe_2O_3 takes place under proper oxygen atmosphere. The oxygen partial pressure is the critical parameter responsible for the mechanochemical reactions. Plausibly, three phenomena govern mechanochemical reactions; (i) the generation of highly energetic and localized sites of a short lifetime at the moment of impact; (ii) the adsorption of oxygen at atomically clean surfaces created by particle fracture; and (iii) the change of activities of the constituent phases arising from a very distorted (nanocrystalline) structure.

...Geiss
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I used rock-magnetic techniques in combination with several other non-magnetic methods, such as pollen analyses (performed by R. Teed), ostracode assemblages (analyzed by B. Curry from the Illinois State Geol. Surv.), stable isotope measurements performed on ostracode shells (supplied by E, Ito) and several sedimentological parameters (particle size distribution, clay mineralogy, org. carbon content, chemical composition etc.) to explore how variations in climatic, vegetational and limnological conditions affect the magnetic properties of the lake sediments, and assist in the construction of a paleoclimatic record for the midwestern United States. Parallel to the study of the lake sediments we undertook an investigation of the glacial gravels, loess units and paleosols to characterize their magnetic properties and assess their influence on the lake sediments.

A combination of X-ray and SEM analyses (performed on magnetic extracts), thermal demagnetization of SIRM acquired at low-T (5 K) and Curie measurements showed that the magnetic carriers in the sediments are (titano)magnetite and maghemite. In two localized horizons we did also find evidence for the presence of iron sulfides (pyrite framboids were observed in the SEM images). The main climatic signal can be found in a combination of grain-size and concentration changes. The figure below shows some of the parameters measured for site PBAS 94-5a. Magnetic susceptibility is used as a proxy for the concentration of magnetic minerals (SIRM and saturation magnetization J_s give more or less identical results), ARM/SIRM is used to characterize the relative abundance of SD-grains, while frequency dependent susceptibility (corrected for para/diamagnetic contributions) is used as an indicator for SP-particles. A simplified paleoclimatic interpretation is shown on the right. The oldest parts of the core are characterized by often massive, clay and silt rich sediments, with variable (but mostly high) concentrations of magnetic minerals. These are coarse grained (titano)magnetite and reflect the magnetic fraction of the glacial sediments surrounding the basin. The following interglacial sediments are characterized by organic rich sediments

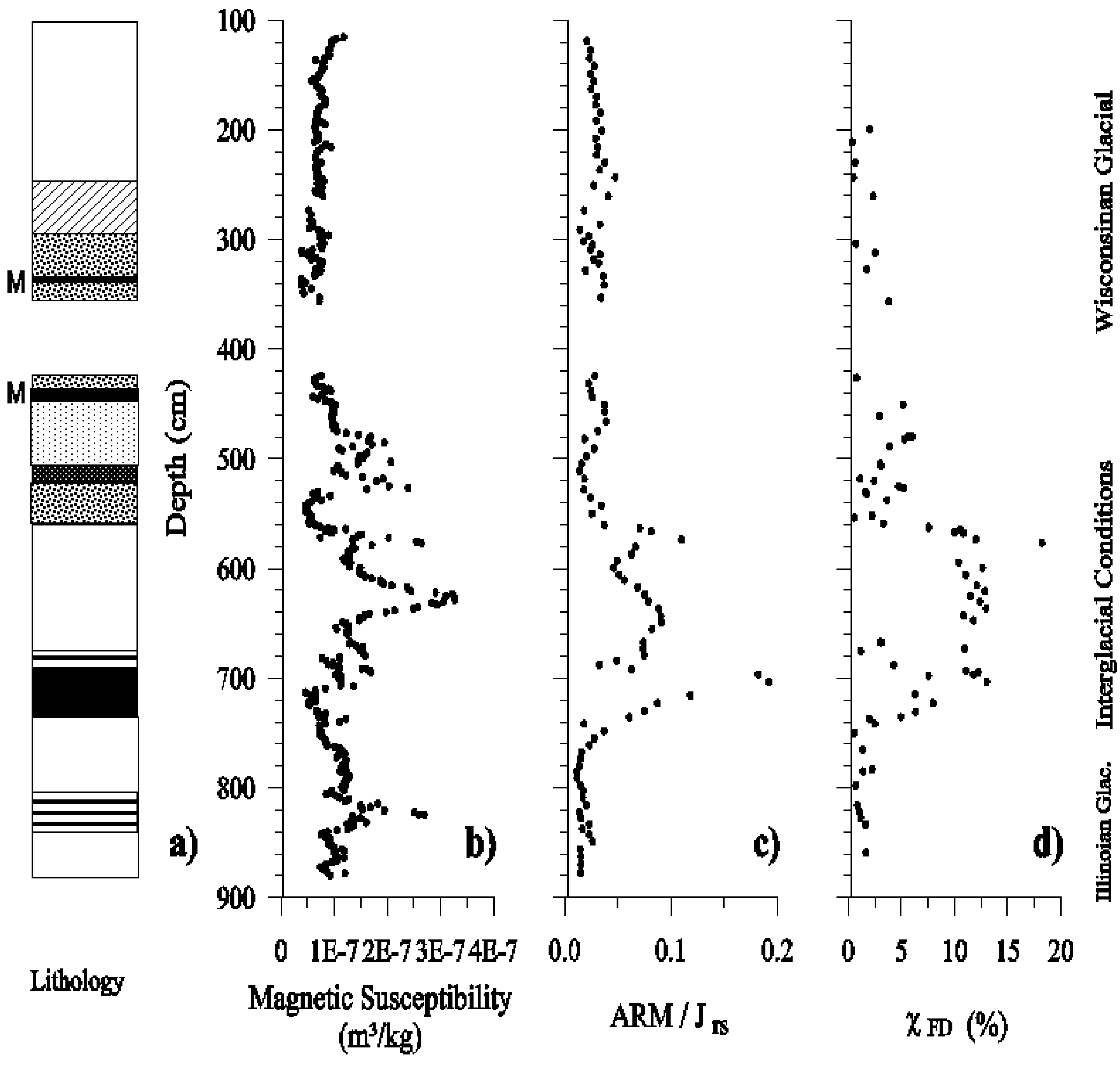

***Figure 1.** Lithology, magnetic properties and paleoclimatic interpretation of Pittsburg Basin sediments. a) lithology (M denotes mollusk-rich layer); b) magnetic susceptibility can be used as a proxy for the concentration of magnetic minerals; c) ARM/SIRM estimates the proportion of SD particles; d) frequency dependent susceptibility χ_{FD} is a proxy for the presence of SP particles. Paleoclimatic interpretation is based on pollen analyses by R. Teed.*

with low concentrations of magnetic minerals. High values of ARM/SIRM and χ_{FD} in combination with low-T experiments show that biogenic magnetite (from magnetotactic and Fe-reducing bacteria) is the main magnetic component in these sediments. During this period dense vegetation decreased erosion rates and organic productivity in the lake was high, likely due to the high water temperatures experienced during this time-period. Mid-interglacial conditions are characterized by dry but equally warm conditions. Deciduous forest was replaced by prairie vegetation and erosion rates increased. Magnetically this period is characterized by high concentrations of fine grained (SD and SP) maghemite which is likely of pedogenic origin and was eroded into the lake. This interpretation is based on a comparison of the lake sediments with an exposure of the Sangamon paleosol in the watershed. The upper 4.5 m of sediment are affected by subaerial weathering and a fluctuating water table. Several paleoclimatic techniques indicate periods of extremely low lake levels, which is confirmed by at least one gravel layer in the upper part of the core. These extremely dry conditions during the Wisconsinan glaciation resulted in a loss of ferrimagnetic iron oxide minerals as they were repeatedly subjected to changes in redox conditions. The sediments are characterized by bright orange stains. Low values of χ, ARM/SIRM and χ_{FD} indicate dissolution of ferrimagnetic particles, resulting in an apparent coarsening of the magnetic fraction. The same sediments are characterized by the presence of magnetically hard minerals, which can be seen in low S-ratios and IRM acquisition curves.

A similar pattern of concentration and grain-size changes has been observed for a Holocene lake South of Minneapolis (Kirchner Marsh, *Geiss and Banerjee*, in press). Initial late glacial sediments are strongly magnetic, with magnetic properties similar to the glacial parent material. Periods when the landscape is covered by deciduous forest show an increase in fine-grained magnetite, most likely of biogenic origin, while drier prairie periods are characterized by increased input of detrital material, either due to higher erosion rates or the deposition of loess/eolian dust.

Our study shows that Pittsburg Basin recorded climatic variations beginning at the end of the Illinoian glaciation (≈125 ka b.p.) until the lake was drained in the early 20th century. Both magnetic and non-magnetic results can be used to construct a robust record of paleoclimatic change. The duration of interglacial climatic conditions, however, is poorly constrained. R. Teed's [1999] interpretation of mostly cool and dry conditions throughout MIS 5d through MIS 2 is based on a comparison of the Pittsburg Basin pollen record with the pollen record of Grand Pile, France. Our interpretation of relatively warm conditions throughout all of MIS 5 - 3 is based on our (questionable) set of OSL-dates, sedimentological evidence from Pittsburg Basin, a speleothem record from Crevice Cave, MO [*Dorale et al.*, 1998 and unpublished data] and various other paleoclimatic data from the midwestern United States, indicating generally warm climatic conditions until the maximum extent of the Laurentide ice sheets (18 ka b.p.).

Now, as a postdoc, I have decided to move on to real lakes. This April, about a week after defending my PhD, I joined Feng Sheng Hu from the University of Illinois to core volcanic lakes in Alaska. We are investigating cores from several sites in southeastern and central Alaska for their potential significance as paleoclimatic recorders. However, dried up and, especially drained, lakes seem to have a certain attraction: For approximately three months now I have been studying windblown sediments originating from Owens Lake, CA.

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Geiss, C.E., and S.K. Banerjee, Comparison of two interglacial records from the midwestern U.S.A., *Physics and Chemistry of the Earth*, in press.

Grüger, E., Late Quaternary vegetation development in South-Central Illinois, *Quaternary Research, 2*, 217-231, 1972.

Teed, R., A >130,000-Year-Long Pollen Record from Pittsburg Basin, Illinois, PhD thesis, University of Minnesota, 1999.

The Magnetic Chef

Christoph Geiss
IRM

Taste of Manhattan Pizza & Pasta
616 Washington Ave SE
(****)

At lunchtime the *Taste of Manhattan* is a busy place. You squeeze yourself through the door, choose from one of their pre-cooked pizzas, it's heated up for you in a big oven, you get pushed towards the cash register, pay, get your slice and then - you have to find a place to sit, which can be difficult. However, it's worth it. *Taste of Manhattan* offers fast, good and cheap lunch fare. The most requested item is pizza, which is usually sold by the slice. One large piece - enough for most people - costs $2.50 (one topping) - $3.00 (two toppings) and there is always a large choice of meat- and animal-lover varieties available. Choices include *rosemary chicken and sundried tomato, feta-basil, plain cheese, pepperoni, sausage and meat, alfredo, eggplant and spinach* and probably a few more. In addition to regular pizza Taste of Manhattan offers *Calzones* and *Strombolis* (all served with tomato sauce). They all come in meat and meatless varieties. A recent addition to the menu is fresh salad and, as far as I remember, it is possible to get soup of the day, though not many people do. Pasta is limited to *spaghetti* with various sauces, *manicotti* or *shells stuffed with ricotta, tomato sauce and mozarella* and *meat or vegetable lasagna*. All of these dishes run around $5.00. If that's too much for you, consider filling up on their 99 cent *sandwiches* or garlic knots, which are a value that's hard to beat (99¢ sandwich limited to one per visit). The quality of the sandwiches, however, depends on the mood of the guy who makes them. So striking up a conversation might yield a bigger lunch. Furthermore, real insiders ask for a scoop of "super hero", but you might try something else if you have a chat with the University President right after lunch. All their stuff - and much more is also offered for carry-out. So if you want to treat us to pizza you know where to go.

...Brachfeld

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Historical observations of temperature, precipitation, sea bird distribution, and ice-shelf stability have shown that the Antarctic Peninsula is extremely responsive to environmental variables. These observations suggest that this region is an ideal setting to examine natural decadal and century-scale paleoclimate variability, provided that suitable records exist. Fjords and deep basins on the continental shelf have proved to be reliable repositories of high-resolution environmental records. A common feature of these records is a magnetic susceptibility signal that is remarkably cyclic during the late Holocene and uniformly low during the middle Holocene. Spectral analysis performed on physical properties time series and paleontologic time-series from cores from the Antarctic Peninsula have yielded century-scale (50-300 years) peaks in spectral power (Leventer et al., 1996; Domack et al., 1993).

The carriers of these susceptibility cycles in glacial-marine sediments were investigated via magnetic and non-magnetic analytical methods, using sediment cores from the Palmer Deep, a basin on the western margin of the Antarctic Peninsula. The *RV Polar Duke* collected a 9-m core, PD92-30, in 1992. The results from PD92-30 and other short cores collected by the U.S. Antarctic Program led to the selection of the Palmer Deep as a drill site during ODP Leg 178.

Magnetic susceptibility shows a strong correspondence with sedimentology and physical properties (figure 2). Intervals of high magnetic susceptibility are massive and often burrowed, have higher than average bulk density and lower than average total organic carbon (TOC) content. Intervals of low susceptibility are laminated and have lower than average bulk density and higher than average TOC content. Ice-rafted debris (IRD) is uniformly distributed throughout the upper 600 cm of the core, and decreases slightly below 600 cm. The abrupt decrease in susceptibility at 600 cm in core PD92-30 corresponds to slightly elevated values of TOC and higher abundance of diatom valves per gram of sediment, but there is no change in lithology at this horizon. Below 600 cm the magnetic susceptibility remains low, although the alternation of massive and laminated intervals continues. This horizon has been interpreted as a shift from a mid-Holocene climatic optimum to the onset of the Neoglacial period in the Antarctic Peninsula (Domack et al., 1998).

Distinct magnetic mineral assemblages were observed in the Neoglacial interval and the mid-Holocene interval. The Neoglacial interval is characterized by multidomain (MD) and coarse pseudo-single-domain (PSD) magnetite. High-susceptibility intervals generally contain coarser grains than low-susceptibility intervals. The middle Holocene is characterized by SP particles and by PSD titanomagnetite, $Fe_{3-x}Ti_xO_4$, where $x \approx 0.3 - 0.6$ (Brachfeld and Banerjee, in review). No magnetic iron sulfides were observed in the middle Holocene interval. Further, interstitial water data collected during ODP Leg 178 indicates that organic matter degradation and sulfate reduction occur 10 meters below the drop in magnetic susceptibility. Therefore, the susceptibility record appears to be free of diagenetic overprints.

During the Neoglacial interval, magnetic susceptibility reflects variable primary productivity. Micropaleontologic data from the low-susceptibility intervals of PD92-30 indicate periods of high productivity, resulting in part from a stabilized water column Leventer et al. (1996). In the Southern Ocean several factors alone or in combination can cause stabilization of the upper water column. These include the presence of a surface layer of low-salinity (low-density) meltwater from sea ice and/or glacial ice, a surface layer warmed by insolation, a decrease in wind stress, or a change in water mass. Leventer et al. (1996) demonstrated that low-susceptibility intervals were characterized by diatom assemblages indicative of melting sea-ice, supporting the meltwater-stabilization scenario. A stratified water column will eventually disintegrate as water mixing reduces the differences in salinity, density and/or temperature that led to the stratification. Mixing of the upper water column along the western Antarctic Peninsula is driven by wind and by storms. Therefore, low-susceptibility intervals in the upper 600 cm of PD92-30 may be interpreted as periods of reduced wind stress and reduced storm intensity and/or frequency, which allowed the stratified water column to persist for longer periods of time, enabling large diatom blooms.

Additional constraints on environmental processes are provided by the change in magnetic grain sizes and composition at 600 cm. Samples from above 600 cm are characterized by multi-domain and coarse pseudo-single domain magnetite whose likely source are the plutonic rocks exposed on Anvers Island and Graham Land. The compositional change to titanium-rich phases at 600 cm suggests a change in provenance from the calc-alkaline intrusives to finer-grained volcanic rocks. Along with higher overall productivity, the climatic optimum may have involved changing sediment transport patterns, possibly the reduction or cessation of locally-derived ice-rafted debris, resulting in a dominance of sediments derived from farther afield (Brachfeld and Banerjee, in review).

Many, many scientists are involved in the analysis of the long cores from the Palmer Deep collected during ODP Leg 178. I look forward to seeing their results at our upcoming post-cruise science meeting in Iceland. And true to my early interests, cores collected from the Palmer Deep and fjords along the Antarctic Peninsula have been u-channeled for paleosecular variation and paleointensity studies. Sorry Chris, you were only half-right.

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Maxwell, James Clerk

b. June 13, 1831, Edinburgh;
d. Nov. 5, 1879, Cambridge

The distillation of the laws of electromagnetism in Maxwell's equations represents one of the great syntheses in the history of science, encompassing the significant results of Faraday, Ampère, Ørsted, Ohm and Coulomb. Beyond that, however, it provided the foundation from which Maxwell developed the idea of electromagnetic waves. Maxwell is also regarded as one of the founders (with Boltzmann) of statistical mechanics and the molecular theory of gases. Under the *nom de plume* of dp/dt (thermodynamically equivalent to JCM) he corresponded with colleagues in verse. The cgs unit of magnetic flux is named for Maxwell ($1 \text{ Gauss}\cdot\text{cm}^2 = 1 \text{ Maxwell} = 10^{-8}$ Webers).

Will mounted ebonite disk
On smooth unyielding bearing
When turned about with motion brisk
(Nor excitation sparing)
Affect the primitive repose
Of + and - in a wire
So that while either downward flows
The other upwards shall aspire?

From the Tait-Maxwell correspondence, 1877
In *The Life of James Clerk Maxwell*
by L. Campbell and W. Garnett

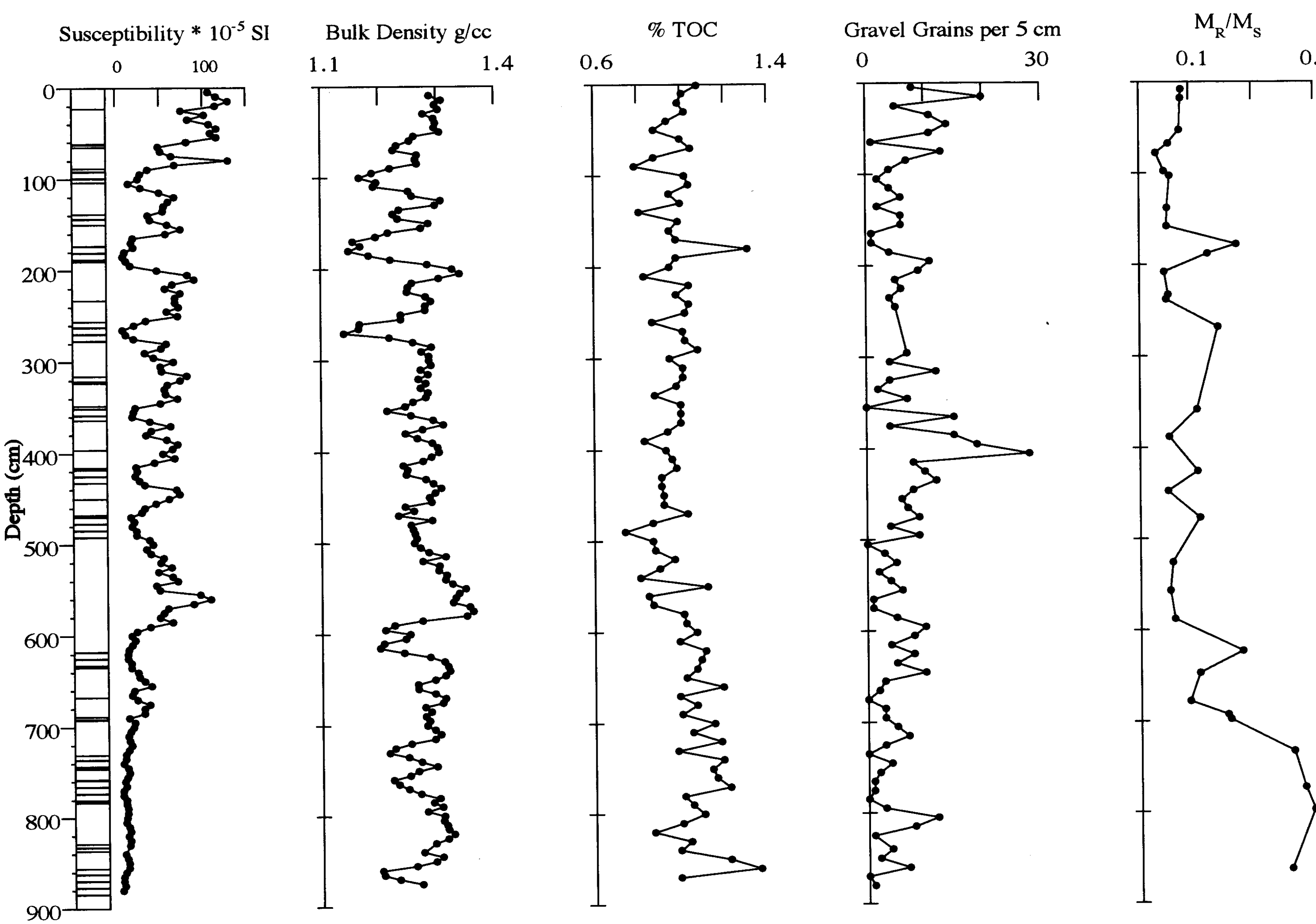
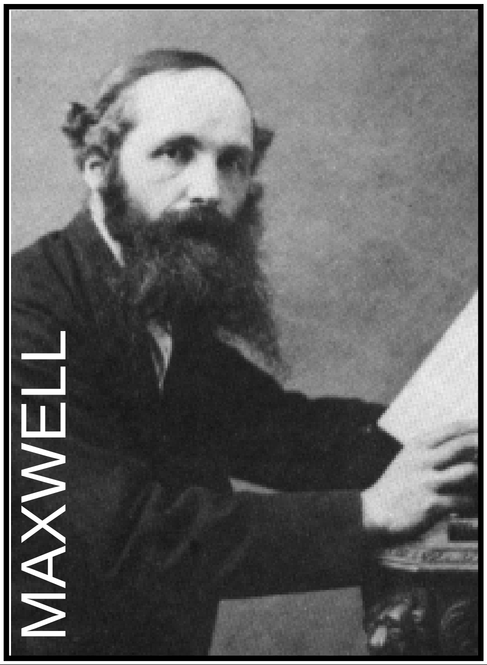


Figure 2. *Magnetic susceptibility and physical properties from core PD92-30. Redrawn after Leventer et al., 1996.*



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