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The GP Compass

The GP Compass: *The focal point for the geomagnetic and paleomagnetic community.*

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News & Announcements

Global Paleopoles

Data Base Off to Good Start

PAGES 748, 758

In July 1987, Phil McFadden of the Australian Bureau of Mineral Resources wrote to Rob Van der Voo at the University of Michigan and to several other paleomagnetists in the U.S. suggesting that the time had come for construction of a paleomagnetic data base. He added that Mike McElhinny was thinking of retiring from BMR and might be interested in the project. He thought funding for the project could perhaps be sought from organizations such as the National Science Foundation. To make a long story short we are now, nearly two years later, well on the way with at least one large component of this suggestion: a global paleomagnetic pole data base being constructed by Mike McElhinny for the entire world.

Plans are also developing for compilations of other paleomagnetic data, such as those gathered in secular variation (C. E. Barton and S. P. Lund), archeomagnetic (R. Sternberg, J. Shaw, S. Burlatskaya and Q. Y. Wei), and paleointensity studies (proposed organizers are M. Kono and H. Tanaka of Japan). Experience gained from working with the paleopoles data base may be valuable for these other components.

The rationale is clear to every paleomagnetist who has had to face a sudden or emergent need to compile results from a different geological period or a new or unfamiliar geographic area for comparison with newly obtained results. Paleopole data are being published at the rate of a dozen or so each month in disparate journals and edited volumes, and no one can aspire to file, catalog, remember, or even find all new results. The pole lists published in the 1960s and 1970s in the *Geophysical Journal of the Royal Astronomical Society*, in 1976 by the Earth Physics Branch in Ottawa, and in the compilations of A.N. Khramov for the Soviet Union went some way to overcome the accessibility problem, but still required an often time-consuming manual search; moreover, those lists stopped appearing in 1980. The danger that data were being lost to the general community almost as fast as they were being generated was very real.

Over the past decade, the amount of information has escalated so much that even for a paleomagnetic specialist the task of going through the literature to extract all available information for a given time period or a certain geographic area is daunting. The database project was conceived to serve the needs not only of those involved in tectonic studies, but also of those who want to analyze more general geomagnetic field problems such as long-term nondipole fields, reversal occurrence and frequency, or the Fisher statistics associated with paleomagnetic poles.

The International Association of Geomagnetism and Aeronomy (IAGA) unanimously passed a resolution on the need for a database at its closing plenary session in Vancouver in August 1987: "IAGA, *recognizing* the importance of paleomagnetic data for studies of the tectonic history of the Earth and for understanding the geomagnetic field and *noting* the lack of any international coordination in preserving and compiling such data, *urges* support for the compilation of both regional and global databases and for international workshops to coordinate the merging of such databases in order to facilitate the use of paleomagnetic data by research workers." The International Lithosphere Commission Working Group 2 and the U.S. Geodynamics Committee expressed support for the idea.

While many workers maintain their own file-card catalogs, and some (for example, Butler, Irving, Khramov, Luyendijk, Pesonen, Soffel, Westphal) have recently compiled regional or time-restricted paleopole lists, the need seemed urgent for a global and integrated data base—an immensely valuable, if quite time-consuming effort. Someone with widespread paleomagnetic experience would be required to gather, assess and structure the data. This is where Mike McElhinny entered, having spent the better part of a lifetime in paleomagnetic data gathering and, most important, being available for the project if some support could be found.

While NSF was sympathetic to the idea, it was not willing to bear the cost alone; fortunately, and with surprising rapidity given the normal bureaucratic process, other countries (Australia, Canada, Federal Republic of Germany, France, Japan, Switzerland, United Kingdom) entertained the proposal on short notice and most have by now made a financial commitment to join NSF in the funding. Concomitant support for two years from Shell Oil Company to Rob Van der Voo has shown the widespread interest that exists for such a compilation, in academic circles and in the industrial research and more applied areas of the community.

Design of the Relational Paleopole Data Base

To give the paleomagnetic community opportunity to provide suggestions for the data base, an international workshop was held in Prague, Czechoslovakia, on June 27-July 2, 1988, preceded by discussions at the American Geophysical Union 1987 Fall Meeting in San Francisco. The discussions have helped shape the project design.

What is a relational data base? Let us note, first, what it is not. To keep the data base from becoming unmanageable, it certainly cannot be expected to be a "data bank" full of raw numbers, such as those generated all over the world in measurement and demagnetization analysis of paleomagnetic samples. While it might be of interest to have such a data bank, the problems of (re-?)entering endless tables and the efforts required to do so in a common format preclude this ideal from being realized in the near future, at least until the world is ready to send diskettes, tapes or CD ROMs in the required format for every study.

To be "relational," the data base is also not a mere catalogue or pole list; instead, the relational data base is ideally suited to "give" answers to specific queries. Examples of such queries are:

- Provide all results from lavas aged between 5 and 10 Ma and sampled between latitudes 10°N and 20°N.
- Give all the paleopoles (co-)authored by A. V. Cox between 1963 and 1983, for results that pass the baked-contact test.
- Give all Cretaceous paleopoles for the African continent that use principal component analysis in the determination of directions from demagnetization.
- List all Cambrian paleopoles from studies where nonzero structural corrections have been applied.
- Give all paleopoles based on dual-polarity magnetizations for the displaced terrane of Stikinia.

Examples of answers to these queries are provided as "user views" in Table 1.

A relational data base provides an efficient process for interrogating the data to yield answers to these queries. The interrogation can involve complex interrelations between data attributes, because the data base is not hierarchically structured along conventional (catalog) lines such as age, continent, author, journal, year, paleopole data, or vice-versa.

Data-base management systems are distinct from data catalogs because of the ability of the former to call on peripheral software to prepare answers to specific questions in a for-

TABLE 1. Some Typical User Views of the Paleopole Data

Query	User View
Give all rocks units of a certain age for continent X	(CONTINENT, ROCKNAME, PLACE, RLAT, RLONG, LOWAGE, HIGHAGE)
Give all paleopoles from continent X for a particular age	(CONTINENT, ROCKNAME, LOMAGAGE, HIMAGAGE, PLAT, PLONG, DP, DM)
Show laboratory tests carried out for result Y	(ROCKNAME, COMPONENT, DEMAGCODE, TREATMENT, LABDETAILS, ROCKMAG)
List all rock magnetic information for a particular age	(ROCKNAME, CONTINENT, LOWAGE, HIGHAGE, ROCKTYPE, ROCKMAG)
Check reversal test for a set of particular results	(RESULTNO, NOREVERSED, ANTIPODAL, NN, DN, IN, KN, EDN, NR, DR, IR, KR, EDR)
List all papers written by a particular author	(AUTHORNAME, YEAR, JOURNAL, VOLUME, PAGES, TITLE)
Give all results from lavas 5-10 Ma, between 10 and 20 N [Select RLAT >10 *and* <20; LOWAGE <10 *and* HIGHAGE >5]	(CONTINENT, ROCKNAME, RLAT, RLONG, LOWAGE, HIGHAGE, PLAT, PLONG, DP, DM)
Give all poles (A. Cox, 1963–1983) with baked-contact test [AUTHORNAME = COX, A.; YEAR >1962 and <1984; TESTTYPE = C]	(AUTHORNAME, YEAR, CONTINENT, LOMAGAGE, HIMAGAGE, TESTTYPE, PLAT, PLONG, DP, DM)
Give all Cretaceous poles for Africa using Principal Component Analysis [Select CONTINENT = AFRICA; DMAGCODE > 3; LOMAGAGE < 144 *and* HIMAGAGE > 65]	(CONTINENT, LOMAGAGE, HIMAGAGE, DEMAGCODE, PLAT, PLONG, DP, DM)
Give all Cambrian poles with non-zero structural correction [Select LOMAGAGE < 570 *and* HIMAGAGE > 505; TILT > 0]	(CONTINENT, LOMAGAGE, HIMAGAGE, TILT, PLAT, PLONG, DP, DM)
Give all poles from Stikinia with dual-polarities [Select TERRANE = STIKINIA, NOREVERSED > 0 *and* < 100]	(TERRANE, LOMAGAGE, HIMAGAGE, NOREVERSED, ANTIPODAL, PLAT, PLONG, DP, DM)

For explanation of entries and abbreviations see Table 2.

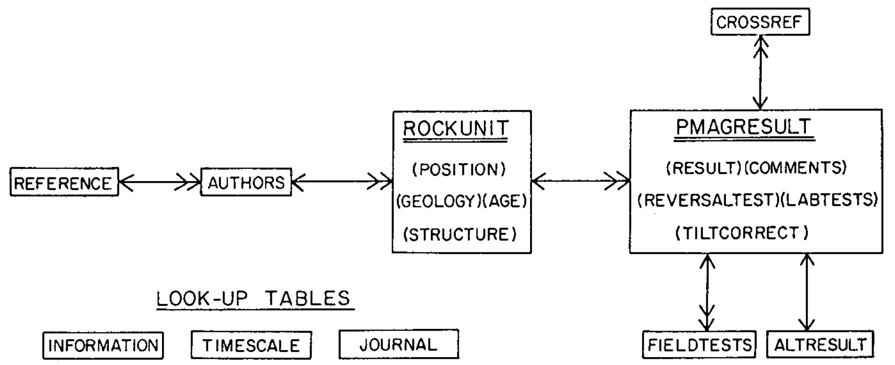

Fig. 1. Flow chart illustrating relations between entities of the Global Paleopole Data Base Program in ORACLE. Single arrows illustrate that there is a direct (one-to-one) association between entities; a single arrow connected to a double arrow shows a one-to-many association. Thus, one reference may have many authors, one rock unit may have yielded many paleomagnetic results, or one paleomagnetic result, based on the mean of directional site-means may be compared with one alternative result based on, say, the mean of site poles.

mat that is ready for analysis by other software. ORACLE has been selected as the preferred system because it can be used on personal computers as well as on mainframes and also satisfies all modern criteria for an efficient relational data-base management system.

The main categories of data for each paleopole are shown in Figure 1 and entries being compiled for each result, as available from the published literature are shown in Table 2. Entries are stored and distributed in ORACLE's memory, but can be called up as "user views," examples of which are in Table 1. A view is an imaginary table made from any combination of entries in the different tables in the data base. It can be manipulated and queried as though it were a real table. The more sophisticated user can even have a view of a view. The views that might be required to answer the five questions posed above are given as examples in Table 1.

McElhinny and Van der Voo seriously contemplated whether to attach any judgmental factors (quality indices) to the paleopoles, such as the B, A, A*, A** system of the Ottawa catalogs, but decided against it. While almost everyone now recognizes the need to separate reliable from outdated or otherwise unreliable entries, it is a delicate and subjective process to assign reliability. Some in the community have expressed opposition to the inclusion of such indices, arguing that each user must carry the responsibility to assess the available information without being able to "hide behind" some quality factor preselected by others. Nevertheless, the entries for each pole can be quickly scanned to see whether criteria are met relating to demagnetization, age and structural control, stability tests, and so forth, so that any user can quickly compile a check list of reliability criteria. Indeed, a user can readily add tables to the data base, imparting a personal "quality" system to the entire data base.

The plan is to eventually extend the data base to include site-means, but not for the time being; not only is this information frequently unavailable in the archival literature, it also would add substantially to the time required to the global data base. It was felt that during a 2-year project like this one, the highest priority should be to have a finished product at the end of 2 years. A global data base cannot and should not take the place of publication and archival in journal issues, but what it can do is extract in data base format the many common attributes for searching according to commonly selected entries.

Compilations to Date

The data-base format of the figure and table of this article was set up in March 1989 by Mike McElhinny and his programmer Jo McElhinny Lock of Gondwana Consultants in Australia. One of the nicer advantages of ORACLE is that it does not store null or blank values; thus, for a paleopole entry that has, say, no information on demagnetization analysis or structural correction, the columns in the table that are unfilled show up in the user views but do not take up space in memory.

The first 1000 entries in the data base cover the paleopoles published in the last decade in the *Journal of Geophysical Research, Geophysical Journal, Bulletin of the Geological Society of America, Geology, Earth and Planetary Science Letters, Physics of the Earth and Planetary Interiors*, and *Journal of Geophysics*. In addition, Rob Van der Voo has prepared a more or less complete list of all Phanerozoic paleopoles based on demagnetization techniques for the cratonic parts of North America, Europe including the Soviet Union west of the Urals, and the Gondwana continents so they can be entered relatively quickly in the near future. Mike and Jo hope to be spending May 1990 in the U.S. and plan to give a demonstration of the data base at the AGU 1990 Spring Meeting in Baltimore. They will be re-

TABLE 2. Relations and Attributes of the Global Paleopole Data Base

Entity	Entries
REFERENCE	(REFNO, YEAR, JOURNAL, VOLUME, PAGES, TITLE)
AUTHORS	(REFNO, AUTHORNO, AUTHORNAME)
ROCKUNIT	(REFNO, ROCKUNITNO, ROCKNAME, PLACE, CONTINENT, TERRANE, RLAT, RLONG, ROCKTYPE, STRATA, STRATAGE, LATSPREAD, LOWAGE, HIGHAGE, METHOD, ISOTOPEDATA, STRUCTDETAILS)
PMAGRESULT	(ROCKUNITNO, RESULTNO, COMPONENT, LOMAGAGE, HIMAGAGE, TESTS, TILT, SLAT, SLONG, B, N, DEC, INC, KD, ED95, PLAT, PLONG, PTYPE, DP, DM, NOREVERSED, ANTIPODAL, NN, DN, IN, KN, EDN, NR, DR, IR, KR, EDR, DEMAGCODE, TREATMENT, LABDETAILS, ROCKMAG, NT, DO, IO k1, ED1, DC, IC, k2, ED2, COMMENTS)
ALTRESULT	(RESULTNO, APLAT, APLONG, KP, EP95)
FIELDTESTS	(RESULTNO, TESTTYPE, PARAMETERS, SIGNIFICANCE)
CROSSREF	(RESULTNO, CATNO,)
	Look-Up Tables
INFORMATION	(SYMBOL, EXPLANATION)
TIMESCALE	(PERIOD, EPOCH, AGE, TOP, BASE)
JOURNAL	(ABBREVIATION, FULLNAME)

Explanation: Entries are underlined to denote links established by ORACLE between entities, usually through entry numbers (e.g., REFNO = Reference Number; CATNO = Catalog Number, for example, of the Ottawa List). LAT, LONG are latitude and longitude, respectively, and are preceded by specifications such as R = rock, S = site, P = pole, AP = alternative pole. LOWAGE and HIGHAGE, and LOMAGAGE and HIMAGAGE denote the lower and upper limits of the rock age and the magnetization age, respectively (if known and as described in COMMENTS), based on METHOD (e.g., fossils, Rb/Sr).

STRUCTDETAILS provides details such as strikes and dips of the structural setting of the sampling localities. B = number of sites, N = number of samples used to calculate the mean DEC or D (= declination) and INC or I (= inclination) with associated statistical parameters KD (precision parameter k) and ED95 (alpha 95); PTYPE denotes entries from which the pole is calculated (e.g., based on site mean directions or on site virtual geomagnetic poles). DP and DM are the semiminor and semimajor axes of the oval of 95% confidence associated with the pole.

NOREVERSED and ANTIPODAL describe the occurrence (%) of reversed samples and to what degree (angle) the normal-polarity (N) and reversed-polarity directions (R) are antipodal. DEMAGCODE describes the demagnetization treatment (0 = no demagnetization, 1 = only pilot demagnetization on some samples, 2 = all samples treated with blanket treatment, 3 = vector demagnetization diagrams or stereonets of direction changes with intensity decay (J/Jo) during demagnetization treatment provided, 4 = Principal Component Analysis used with vector demagnetization diagrams or stereonets with J/Jo, 5 = same as (4), but for multiple treatments with different (chemical, thermal, alternating field) demagnetization techniques that successfully isolate component directions.

LABDETAILS and ROCKMAG provide other information about, for instance, maximum demagnetizing fields and rock magnetic experiments. Also given are details about structural corrections for N = NT measurements before (0, 1) and after (C, 2) tilt correction. TESTTYPE describes field and stability tests, such as the fold, baked contact, conglomerate or reversals test.

turning in fall 1991 to the U.S., where Mike hopes to teach a course at the University of Michigan and to finalize the product together with Rob Van der Voo.

Acknowledgments

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Meetings

Meeting Report

NATO Granulite Conference

PAGES 752-753

On September 5-9, 1988, 83 participants from 20 different countries gathered in Clermont-Ferrand, France, for the workshop Petrology and Geochemistry of Granulites and Related Rocks. All geoscience disciplines were represented. The workshop was cosponsored by Université Blaise Pascal, UFR Scientifique et Technique, Centre National de la Recherche Scientifique, International Lithosphere Program (working Group 2c), IGCP Project 235, Société Française de Minéralogie, Ministère de l'Education Nationale (DAGIC), Ministère des Affaires Etrangères (DGSTD), Conseil Régional d'Auvergne, Conseil Général du Puy de Dôme, Mairie de Clermont-Ferrand.

Session topics at the meeting were chosen according to the major themes of the contributed abstracts. These represent an up-to-date reflection of centers of interest in this field. All abstracts quoted in this report have been published in *Terra Cognita, Vol. 8*, No. 3, pp. 233-275. The following is a summary of highlights in each session.

The first day focused on Regional Syntheses—descriptions of granulite terrains throughout the world (Arndt et al., Barbey and Raith, Barbosa, Bingen et al., Hensen and Warren, Lieberman, Mogk, Perchuk and Gerya, Percival, Tait, Thost et al., Wang). This set the scene for more detailed, thematic discussions.

The European Hercynian Belt was the object of special attention, partly reflecting the provenance of the contributors. In this region there are some very high-pressure granulites (~15 kbar) (Bakun-Czubarow, Fabriès and Latouche, Libourel and Vielzeuf) that have been commonly overlooked in recent assessments of the P-T conditions of granulite metamorphism. This is surprising, since granulites were first defined in the Granulitgebirge in Saxony. During the meeting, emphasis was mainly on metamorphic and magmatic processes related to granulite formation. Apart from Kornprobst and Vielzeuf, very little was said about tectonic processes which brought granulite terrains to the surface. However, Marchand showed that in the Hercynian Belt, early high-pressure granulites can be interpreted as markers of thrust nappes.

In his review of the Ivrea Zone (northern Italy), Schmid introduced the idea that granulites are the high-grade residues left after removal of a major melt fraction. This became one of the recurring themes (and arguments) in the conference (see also Paglionico et al., for a comparison with the granulites from southern Calabria). Nd isotopic data showed that ultramafic and mafic dikes in the Balmuccia peridotite (Ivrea Zone) had been affected by two types of metasomatism, one crustal, the other involving mantle-derived fluids (Voshage et al.).