

GP34A CC: 519 B Wednesday
1530hFour Decades of Paleomagnetism in
Canada III (*joint with T, V, NS*)

Presiding: M T Cioppa, University of
Windsor; R Ernst, Geological Survey
of Canada

GP34A-01 1530h

An economic geologist's tribute to Dave
Symons - paleomagnetist
extraordinaire

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Determining the age of emplacement of Mississippi Valley-type (MVT) lead-zinc deposits has, until recently, been the most significant impediment to a clear understanding of their genesis. Lacking knowledge of timing of ore emplacement, MVT genetic models could be proposed without annoying age constraints and could therefore be linked to virtually any geologic event or process. The result, for decades, has been a plethora of genetic models lacking a universal means of testing their validity or providing guidance for either mineral exploration or academic research. Dr. Symons' pioneering research on the application of paleomagnetic techniques to dating Mississippi Valley-type and other sediment-hosted ore deposits has resulted in a quantum leap in understanding when and where these deposits formed in Earth history. His research on nearly two dozen MVT deposits or districts worldwide has shown that more than 70 percent of these ores formed within two time-periods representing only 3 percent of Earth history. The first of these occurred during the Devonian-Permian with the second being the Cretaceous-Tertiary period. These dates show that a majority of MVT deposits formed during large contractional tectonic events while only a minority correspond to extensional tectonic events in Earth history. This remarkable observation has had huge implications for the genesis of this type of mineral deposits by demonstrating that migration of MVT ore fluids is not a natural consequence of basin evolution; rather, MVT deposits form mainly where platform carbonates are hydrologically connected to uplifted orogenic belts generating topographically-driven fluid migration. For example, age dating of MVT deposits has shown that in excess of 75 percent of the combined metal in dated deposits resulted from uplift associated with assembly of Pangea in Devonian through Permian time. David Symons' research has therefore significantly contributed to understanding links between global tectonic events and fluid migration in the Earth's crust and brought a new vision to understanding ore-formation within a broad context of earth processes.

GP34A-02 1545h

Paleomagnetic Reconstruction of
Post-Paleozoic Tectonic Motions for
the Intermontane and Yukon-Tanana
Terranes of Baja British Columbia

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Paleopoles from 42 Mesozoic and Cenozoic rock units in the Intermontane Belt (IMB) and Yukon-Tanana (YT) terranes are deemed to be sufficiently represented paleomagnetically and well dated radiometrically to merit consideration. Unlike previous analyses based on paleoinclination only that have led to estimates up to ~ 3500 Km for northward (poleward) displacement of Baja BC relative to the North American craton, the pattern of both paleoinclination and paleodeclination are used to assess the reliability of each paleopole. The analysis indicates that: 1) the YT terrane is autochthonous or parautochthonous; 2) the IMB terranes rotated steadily atop the craton by $16^\circ \pm 6^\circ$ between 54 Ma and the present, accommodated by extension in the south and compression in the north; 3) the IMB terranes were rotated a further $35^\circ \pm 14^\circ$ and translated northward by $8^\circ \pm 7^\circ$ (900 Km) from 102 to 54 Ma, consistent with geological estimates for the

northward displacement of interior Baja BC; and, 4) the Cache Creek, Quesnel and probably Stikine terranes were part of Baja BC since Early Jurassic.

GP34A-03 1600h INVITED

Paleomagnetic Perspectives:
Contributions of H.C. Palmer

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With a broad background in petrology, structure, and tectonics, H.C. Palmer undertook a new career path in paleomagnetism in 1964 under a Canada Council post-doctoral fellowship at the University of Western Ontario. Like many paleomagnetists of that time, he became largely self-taught as he explored paleomagnetic methods and rock magnetism. His research, although primarily focused on Canadian Precambrian themes such as dike swarms, Grenville deformation, and Logan's loop, encompassed also studies in the U.S., Europe, South America, and Australia. Among his earliest studies was the first paleomagnetic investigation of Warren Carey's Bolivian orocline, preceding dozens of subsequent investigations by other workers. Palmer's research objectives on a broad scale incorporated paleomagnetic evidence into major tectonic events, especially those involving terrane accretion in the Canadian Cordillera and Canadian shield. He was also attentive to the important minutiae of mineralogical transformations and associated effects on magnetizations which influence tectonic interpretations, as well as to the importance of age relationships and correlations for correct paleomagnetic interpretations. He worked with a wide variety of mainly igneous rocks, of many tectonic and structural settings, ranging from silicic ashflows to ultramafic intrusions. This paper highlights selected contributions of Palmer's wide-ranging career to the fields of paleomagnetism and rock magnetism.

GP34A-04 1615h

Mapping Flow Patterns in Nipissing
Sills of the Southern Province,
Canadian Shield: a Magnetic Fabric
Study

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It has been proposed that large sill provinces are fed either vertically from underlying source areas or via lateral flow in giant dyke swarms. Ca. 2217 Ma Nipissing sills of the Huronian sedimentary basin of the Southern Province of the Canadian Shield provide an ideal test of these models because they are well exposed, readily accessible for sampling and mostly unmetamorphosed north of the Murray fault. Buchan et al. (1998) have suggested that the Nipissing sills were fed laterally from a mantle plume centre 1500 km to the northeast in the Ungava bay region via 2216 Ma Senneterre dykes which form part of a giant radiating dyke swarm. Evidence that Nipissing sills were fed from the side rather than from underneath would support the model of a distant source. Anisotropy of magnetic susceptibility (AMS) is an efficient technique for determining flow directions in magmatic rocks. In this study, we present results from approximately 130 sites in Nipissing sills. Sites in the northern Cobalt plate exhibit sill-like patterns with maximum susceptibility axes oriented NNW-SSE and are thus compatible with magma emplacement from a distal source rather than from local subjacent magma chambers. Sites farther south where the Nipissing sills are gently folded exhibit few sill-like patterns. Dyke-like patterns are more common in this region and appear to reflect the east-west tectonic grain rather than primary magmatic flow patterns. Buchan, Mortensen, Card and Percival, 1998, Can. J. Earth Sci. 35: 1054-1069.

GP34A-05 1630h

Paleomagnetism in northern Alaska
(and the career of David Symons),
from displaced terranes on the west
coast of North America to the age
dating of base metal ores

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Paleomagnetism of barren and mineralized Paleozoic sedimentary rocks of the Red Dog Zn-Pb deposit in the Brooks Range Mountains of northern Alaska isolated several components. Mineralized and barren rocks with quartz alteration have a steep west-southwesterly magnetization retained by magnetite (N=16, D=247, I=73, k=73). Fluid inclusions indicate that the quartz formed during deep burial and Ar/Ar dating yielded an age of 126 Ma. Heavily mineralized rocks plus mineralized shales lacking quartz replacement have a shallower southwesterly magnetization carried by pyrrhotite (N=11, D=220, I=51, k=28). Geological features and Re/Os dating indicate that the ore formed in the late Paleozoic. A Mississippian igneous sill (344 Ma, Ar/Ar) in the mine has a south-west and shallow magnetization carried by magnetite (1 site). Ultramafic igneous intrusive rocks from Asik Mountain 100 kms south of Red Dog, have been indirectly dated at about 150 Ma (K/Ar) and have a west-southwesterly magnetization carried by magnetite (N=11, D=255, I=82, k=19). Tectonic models for the Mesozoic origin of northern Alaska can be grouped into three categories: 1) contiguous to ancestral of North America; 2) peri-autochthonous with angular displacements; and, 3) allochthonous terranes accreted to ancestral North America. The combination of geologic, radiometric and paleomagnetic data from Red Dog allows for both testing of the models and paleomagnetic dating of the Red Dog ores. The data can only be collectively explained by Mississippian syngenetic mineralization and pyrrhotite magnetization, Mesozoic northward translation and counterclockwise rotation of a displaced terrane (aka "The Alaskan Terrane Wreck") and, finally, deep burial resulting in remagnetization of some of the ores associated with quartz replacement.

GP34A-06 1645h

Saturation Isothermal Remanent
Magnetization Crossover Plots: Case
Study for a Bimodal Population of
Low and High Coercivity Magnetic
Minerals

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Saturation isothermal remanent magnetization (SIRM) crossover plots are a simple way of determining the identity and domain size of magnetic minerals in rocks, through the use of SIRM acquisition and demagnetization curves and the position of the crossover point of the curves. About 66% of the Upper Ordovician Red River carbonate specimens from Manitoba outcrops show anomalously high crossover points when the standard methodology is followed i.e. the isothermal magnetization intensity values are related to the values obtained at 900 mT. The source of this problem is twofold: first, that the carbonates contain a mixture of magnetite and some amount of hematite influencing the position of the crossover points; and second, that the IRM acquisition values were measured up to 2000 mT because of this mixture. For cases where the influence of the higher coercivity minerals on the IRM acquisition curves for the lower coercivity minerals is low, we suggest that the methodology should be changed slightly. The value of the IRM obtained at 400 mT, equivalent to saturation of magnetite and pyrrhotite, should be considered a modified SIRM for the purpose of determining the crossover points. Thus, the modified crossover points should still be able to

give (within some degree of error) valuable information for the domain state of lower coercivity minerals when mixed in a rock with higher coercivity minerals. Comparison of these modified crossover points to crossover points obtained using the normal methodology for non-hematite-bearing specimens from the Red River carbonates in the subsurface shows similar distributions. We also suggest that if the acquisition curves are extended to at least 2000 mT, it will be significantly easier to identify samples containing a mixed population of low coercivity (magnetite or pyrrhotite) and high coercivity minerals (hematite or goethite).

GP41A CC: 220 C-E Thursday 0830h

Climatic and Anthropogenic Changes to the Environment: Contributions From Magnetism Posters (joint with GC, PP)

Presiding: S K Banerjee, University of Minnesota; F Lagroix, University of Minnesota

GP41A-01 0830h POSTER

Magnetostratigraphical Results From the Pampean Loess of Argentina

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Loess deposits in the northern hemisphere have proved to be excellent magnetostratigraphical archives. Their southern hemisphere counterparts have been much less intensively investigated. We report results from a study of Argentinean loess exposed in three sequences in the city of La Plata, Buenos Aires Province that span the last million years. Magnetic susceptibility values span one decade ($20\text{--}250 \times 10^{-8} \text{m}^3/\text{kg}$), but hysteresis parameters, IRM acquisition and thermomagnetic curves all indicate a remarkably uniform magnetomineralogy dominated by magnetite. Magnetic susceptibility tends to be higher in loess than in the inter-bedded paleosols. This favours the wind-vigour model as opposed to the pattern resulting from pedogenesis. However, values of frequency-dependent susceptibility (F) differ significantly from either model: at La Plata, $F=3.5 \pm 1.2\%$ (st.dev.) ($n=130$), at Kurtak, Siberia (a wind-dominated site) $F=0.8 \pm 0.4\%$ ($n=340$), and at Luochuan, China (a pedogenically-dominated site) $F=8.3 \pm 1.9\%$ ($n=111$). These differences may be compositional in that Argentinean loess contains a large fraction of volcanic material. We are currently pursuing this suggestion by grain-size and magnetic separation studies on a $\sim 100,000$ -yr-old volcanic ash layer embedded in a typical eastern Argentinean loess profile. First results indicate that the ash has F values ranging from 0.8% for the grains smaller than $63 \mu\text{m}$ to 2.6% for the $100\text{--}140 \mu\text{m}$ fraction.

GP41A-02 0830h INVITED POSTER

Enviromagnetism - Quo Vadis?

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Environmental magnetism is a rapidly growing research field which often is tied technically to paleomagnetism and rock magnetism investigators. The magnetic signals and the refinement of magnetic measurement techniques of environmental materials (e.g. dusts,

soils or other sediments) are in the focus of environmentalists. For the characterisation of environmental processes, the magnetic properties are just one of a variety of proxies such as sedimentological or geochemical signatures. Hence environmental interpretation is strengthened by an interdisciplinary proxy approach, which is necessary to understand the complex and still poorly known interaction between geological, physical, chemical, biological and anthropogenic processes involved in the production and transport of environmental materials. This was already recognized by Gustaf Ising when he interpreted the susceptibility of varved clays in Sweden. Here we want to focus on the importance of more open-minded active cooperation amongst all environmentalists. Cooperation provides environmentalists with better tools for interpreting their measurements. On the other hand, the unexpensive, fast and non-destructive characterization of environmental materials using magnetic methods offers a unique possibility of monitoring natural and anthropogenic processes for a broad range of disciplines. We plan to review the present state of environmental magnetism using a few examples from different environments. We will illustrate with a case study how forces amongst environmentalists could be joined better when dealing with problems of urban pollution.

GP41A-03 0830h INVITED POSTER

Environmental Application of Sedimentary Magnetic Measurements: Successes and Problems

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Environmental changes affect sedimentary basins, inducing either clear (i.e. stratigraphic cycles) or subtle oscillations in sedimentary sequences. The study of past environmental changes requires determination of reliable and sensitive proxies in sedimentary sequences at an appropriate resolution. Magnetic particles in sediments may be promptly detected, and semi-quantitatively characterized, with non-destructive magnetic measurements in specialized laboratories, taking advantages of progressive developments in instrumental technology and analytical protocols. Environmental magnetism developed as a viable and original approach to the study of present anthropogenic pollution as well as of past environmental changes. Detailed analyses of stratigraphic trends in composition, abundance, grain-size and shape of magnetic particles in sedimentary sequences were often successful in revealing climatically driven signals at a wide range of time scales and in pointing out analogies and differences in the response of various sedimentary basins to past climatic and tectonic events. Some selected examples will be discussed in this talk. Diagenesis, however, is also liable to induce significant changes in the magnetic mineralogy of sediments, compromising the evaluation of original magnetic signatures. Bacterially mediated synthesis of new magnetic phases as well as oxidation or reductive dissolution of iron in marine sediments are widespread phenomena that needs to be properly addressed in environmental magnetic studies. In this talk, I will provide a personal perspective on the challenges facing applications of sedimentary magnetic measurements to reconstructions of past climatic changes and on the broad problems related to diagenetic effects in sedimentary sequences.

GP41A-04 0830h POSTER

Magnetic Properties as an Assessment Tool for the Distribution and Fate of Heavy Metals in Estuarine-like Environments. The Study Case of the Galician Rias (NW Spain)

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Magnetic properties are successfully used to assess the heavy-metal adsorption capabilities of coastal sediments in NW Spain. A double approach using geographically and vertically distributed data provides a valuable insight into the response and evolution of coastal systems under increasing anthropogenic pressure, and a critical information for environmental management of these areas. The study is based in measurement of low-field susceptibility of over 200 samples of from the top 10 cm of seabed sediment of the Rias of Vigo and Pontevedra in NW Spain (1 per square km).

The basic pattern showed a significant increase of susceptibility towards the open sea and away from polluted continental influenced areas, locally controlled by sediment texture, provenance and local hydrodynamic regime. Vertical variability of the susceptibility was also studied in 80 samples (1 every 3 cm) obtained from three 60 to 80 cm long gravity corers in the Ría de Pontevedra. This showed a very strong decrease in susceptibility with depth related to the early diagenetic evolution of iron oxides and oxyhydroxides. Further analysis comprised measurement of basic hysteresis parameters, ARM, IRM, temperature and frequency dependence of the susceptibility, sediment texture, analysis of major and trace elements, SEM and TEM investigation of the magnetic fraction. Statistical analysis of all the available data showed a significant negative correlation between elemental contaminants and magnetic susceptibility, ultimately controlled by wave climate that strongly drives the sediment distribution and their early diagenetic path. This work underlines the capabilities of magnetic properties to identify and assess coastal processes conditioning the bioavailability of certain heavy metals, particularly in areas in which there is a significant coupling between the hydrodynamic and geochemical processes. Special consideration will be given to the dissolution and nucleation of relevant magnetomineralogical phases during the early stages of diagenesis.

GP41A-05 0830h POSTER



Rapid In-situ Measurement of Magnetic Susceptibility in Unconsolidated Lake Sediments

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Magnetic susceptibility measurements can provide a useful indicator of anthropogenic effects in lake basins, including the onset of land clearance, forest fires, soil erosion and as a proxy for estimating contaminant levels in sediment. Susceptibility is commonly measured on whole or split cores, or on core sub-samples, but coring can be expensive and time consuming where a large number of profiles are required to correlate and map sediment volumes. Post-sampling mineralogical changes in cores are also a potential concern. An alternate approach investigated in this study is to obtain near continuous in-situ measurements of sediment volume susceptibility (k) using a probe driven into the lake bottom. An inexpensive proto-type probe was constructed using a Bartington MS2-F sensor mounted in waterproof housing with an extendable 10 m handle. Several calibration runs were made in a laboratory test column to determine the probe response characteristics and repeatability. Testing showed that the effective sensing volume is a 0.8 cm radius around the probe tip and that edge effects from sensor shoulders are negligible. The probe was then used to measure the thickness and distribution of a post-colonial sediment layer in a shallow coastal lagoon (Frenchman's Bay) in western Lake Ontario. Volume susceptibility profiles were collected at 40 locations by driving the probe up to 2.5 m into the lagoon bottom sediments at 2 cm measurement intervals. The in-situ volume susceptibility profiles were then compared with volume and bulk susceptibility measurements obtained on 10 vibracores extracted from the lagoon. The probe measurements showed comparable resolution to the core-derived data and closely paralleled the core susceptibility curves. The base of the post-colonial sediment layer was identified by an abrupt increase in magnetic susceptibility at 0.5-1.5 m depth. The marker horizon was correlated across the lagoon and the thickness and volume of the anthropogenic layer was estimated. The results demonstrate that in-situ susceptibility measurements using a sediment probe can provide a rapid and highly repeatable method for correlating shallow stratigraphic boundaries within unconsolidated lake bottom sediments.