Surveys in Geophysics (2005) 26:507–510
DOI 10.1007/s10712-005-1756-9

PREFACE

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Working Group I-2 of the International Association of Geomagnetism and Aeronomy (IAGA) held its 16th Workshop on Electromagnetic (EM) Induction in the Earth in the city of Santa Fe, New Mexico, USA on June 16–22, 2002. Santa Fe is the second oldest city in North America, currently is the capital of the State of New Mexico, and is famous for its scenic beauty. The Santa Fe workshop was preceded by a pre-workshop called SEMI (Summer Electromagnetic Immersion) on June 13–15, 2002. SEMI featured hands-on experience for all participants using the latest electromagnetic equipment and software provided by industrial manufacturers and developers. Companies that participated in SEMI were Electromagnetic Instruments (EMI), Geometrics, Geonics, Geosystem/GSY-USA, Phoenix Geophysics, Sensors and Software, and Zonge Engineering and Research Organization. These industry partners also supported the 16th Workshop along with AOA Geophysics, the Gerald W. Hohmann Memorial Trust, KMS Technologies, Los Alamos National Laboratory, San Diego State University, U.S. Department of Energy, U.S. National Science Foundation, and Woods Hole Oceanographic Institution.

The 16th Workshop program was divided into twelve scientific sessions, four of which were introduced by invited reviews. Traditionally, the reviews are published in a special issue of *Surveys in Geophysics*. These special issues have become successive landmarks in the science of electromagnetic geophysics. The topics for the reviews vary from workshop to workshop since they are selected to reflect recent advances, highlight maturing areas of interest, and stimulate new directions of research. Reviews at the 16th Workshop were presented by Robert L. McPherron on the physics of natural magnetic pulsations, Juanjo Ledo on the comparison of two-dimensional (2-D) versus three-dimensional (3-D) data interpretation, Georg Nover on the electrical properties of rocks in the crust and mantle, and Karen R. Christopherson and S. N. Sheard who discussed EM applications in the petroleum, mining, engineering, and environmental industries.

Robert McPherron's paper, "Magnetic Pulsations: Their Sources and Relation to Solar Wind and Geomagnetic Activity" discusses the properties of natural ultra low frequency (ULF) EM waves observed at Earth's surface.

Most of these waves are the product of physical processes in the solar wind or the Earth's magnetosphere. The magnetosphere itself is a resonant cavity and a waveguide for waves that propagate through it. The cavity modes couple to magnetic field line resonances that drive electric currents in the ionosphere. These ionospheric currents re-radiate energy as electromagnetic waves that propagate to the ground where they are used as natural ULF sources for EM techniques such as the magnetotelluric (MT) method. MT measurements on Earth's surface can remotely sense the conditions in the solar wind and the magnetosphere as well as the subsurface electrical conductivity distribution in Earth. Using the wave characteristics discussed by McPherron and the space weather reports from NASA's web site allows one to predict the ULF waves expected at a given latitude and local time. It is almost never correct to assume that plane ULF waves are incident on Earth from outer space.

Juanjo Ledo's discussion of "2-D versus 3-D Magnetotelluric Data Interpretation" is a must read for MT practitioners since 3-D modeling and inversion are still not routine and fast, accurate 2-D computer codes are still necessary tools for interpretation in 3-D environments. Ledo describes EM fields generated by 3-D bodies mathematically and physically using terms that separately express the galvanic and induction effects. Numerical responses of 3-D bodies embedded in homogeneous or 2-D regional backgrounds lead to general conclusions on the validity of using 2-D algorithms to interpret actual 3-D structures. One general result is that both inductive and galvanic effects will affect a homogeneous regional response when 3-D conductive bodies are present, but if the 3-D bodies are relatively resistive, the regional response is influenced mainly by galvanic effects. In 3-D numerical studies presented by Ledo where the regional background resistivity is 2-D, the choice of using the 2-D transverse electric (TE) mode or the transverse magnetic (TM) mode is defined by the regional strike. If a 3-D body's long axis is perpendicular to the 2-D regional strike, the TE-mode is affected mainly by galvanic effects whereas the TM-mode is affected by both galvanic and inductive effects. In this case, 2-D interpretation of the TE mode is better. If the long axis of the 3-D body is parallel to the regional 2-D strike, the situation is opposite: the TM-mode is mainly influenced by galvanic effects and the TE-mode is affected by both galvanic and inductive effects. Here, the TM-mode is more suitable for 2-D interpretation. These conclusions contrast with the long-held belief that when interpreting 3-D MT data using 2-D algorithms, it is best to use the mode identified as TM in the presence of 3-D conductive bodies and the TE-mode when the 3-D bodies are resistive. Ledo concludes that his results represent guidelines, and there are no general statements that are valid for all situations.

The inaccessibility of most of Earth's interior means that the interpretation of the EM soundings in terms of the composition, temperature, pressure, and underlying geology depends largely on laboratory experiments that

simulate the expected conditions. Therefore, "Electrical Properties of Crustal and Mantle Rocks – A Review" by Georg Nover takes on critical importance. Nover reviews the important mechanisms by which rocks allow the conduction and displacement of electric charge. These include electrolytic conduction through fluid-filled pores, semiconduction in electrolyte-free regions such as in olivine that dominates the upper mantle, and electronic conduction in Earth materials such as ores minerals and graphite. The influence of aqueous solutions and/or partial melts can be the most important factors in increasing electrical conductivity if the phases are interconnected along grain boundaries or in cracks. Temperature controls the number and mobility of charge carriers, whereas oxygen fugacity controls how much charge an external EM field can move. Electrical measurements in laboratory settings meant to simulate Earth *in situ* are made in high temperature-high pressure cells. The results are then scaled up to geologic conditions. Impedance spectroscopy allows the measurement of the frequency dependence of the complex electrical conductivity of Earth materials. This helps to unravel the key processes that dominate in different regions of the frequency spectrum. Nover reviews recent laboratory findings and pays tribute to Al Duba and Tom Shankland, who pioneered the application of laboratory electrical measurements. Their work led to the understanding of relationships that govern the physical and chemical state of Earth's crust and upper mantle.

The final review paper, by S. Nick Sheard, Terry Richie, Karen Christopherson, and E. Brand entitled "Industry Applications of EM – Mining, Environmental, Petroleum, and Engineering" provides examples of the successful application of EM methods to base metal and petroleum exploration and environmental problems. A historical sketch of commercial EM methods traces the development first as a "bump" or anomaly detector through the birth of EM as a mapping tool. Surface, airborne, and marine EM operations are discussed using case histories. A tabulation of 120 papers dealing with EM exploration between 1998 and 2002 reveals that the overwhelming number of applications now use EM as a mapping tool in conjunction with computer modeling. EM techniques are described as "a front line tool" in the exploration for base metals, and the authors predict expanded use in groundwater, hydrocarbon, and geothermal problems.

The EM workshop in Santa Fe attracted over 200 scientists from 28 countries. Besides the four review papers, there were 223 contributed abstracts; 67 papers were given as oral presentations and the rest were displayed as posters that remained up for the entire week-long workshop.

The superb setting of Santa Fe allowed workshop attendees to visit art galleries and museums, and sample the unique cuisine of Northern New Mexico. The traditional daylong excursion gave everyone the opportunity to

experience the stunning contrasts that earn New Mexico the motto of ''Land of Enchantment.'' Visitors spent one day exploring the ancient cliff dwellings of Bandelier National Monument; taking in the science museum at Los Alamos, the birthplace of the atomic age; and visiting a Native American pueblo (village). An evening barbecue celebrated the historic ranching traditions of the area and the final banquet featured Latin entertainment and a dance band. So, the workshop not only served as the premier venue for EM researchers around the world to exchange research results and new developments, it rekindled old friendships and ignited new ones. The EM induction workshops continue to foster countless international collaborations befitting an earth science. The next workshop will be held at the National Geophysical Research Institute in Hyderabad, India in October 2004.