is no operational satellite-borne L-band radiometer today, plans are underway to deploy one by the end of the decade. During the Soil Moisture Experiments in 2002 (SMEX02), the Passive and Active L and S-band (PALS) instrument was flown over the Walnut Creek Watershed in Iowa. This agricultural region was selected to facilitate testing of microwave remote sensing algorithms under conditions of highly variable and sometimes dense vegetation cover. L-band brightness temperature observations from PALS were used to retrieve near-surface soil moisture for conditions representative of the dominant corn and soybean land covers in the watershed. Sensitivities of the retrieved soil moisture to surface temperature, surface roughness and the vegetation B parameter have been evaluated for both crops. Retrievals for corn were found to be highly sensitive to the vegetation B parameter, while retrievals for soybeans were most sensitive to surface roughness. The vegetation water content of approximately 4 kg/m2 for the corn sites appears to be high enough to make soil moisture retrievals problematic, but retrievals appear relatively robust for soybeans with a vegetation water content of 0.3-0.7 kg/m2. For both corn and soybeans there is considerable overlap in the parameter spaces (combinations of surface roughness and vegetation B parameter) that yield accurate moisture retrievals for three wet days analyzed, but these parameter values do not translate well to dry conditions. This may indicate potential deficiencies in the roughness and vegetation correction algorithms for agricultural areas and raises concerns about global operational soil moisture retrieval from satellite-borne microwave sensors.

H11B-05 0930h

Horn antenna GPR measurement of crop canopy biophysical and near-surface hydrologic parameters

Guy Serbin[1] (+1-435-757-8459; gserbin@mendel.usu.edu)

Dani Or[2] (dani@engr.uconn.edu)

Philip Rasmussen[1,2] (philr@ext.usu.edu)

[1]Department of Plants, Soils and Biometeorology, Utah State University UMC4820, Logan, UT 84322-4820, United States

[2]Department of Civil and Environmental Engineering, University of Connecticut 261 Glenbrook Road, Unit 2037, Storrs, CT 06269-2037, United States

GPR with a suspended 1 GHz horn antenna was deployed in the greenhouse and field for measurements of wheat canopy properties and soil water content dynamics. Dielectric permittivity and water content of soil and canopy were independently determined from surface reflection (SR) and from signal propagation time (PT) to a reflective layer (aluminum foil) underlying plant canopy or a soil layer. SR values progressively decreased with increasing canopy biomass according to Beer-Lambert type relationships. More attenuation was measured for the denser greenhouse dwarf wheat than in the field study. In contrast to SR measurements, PT values remained unaffected by canopy thereby provided an accurate account of soil water content dynamics. Canopy removal restored SR-based soil water content measurements to PT values as confirmed gravimetrically. Bulk canopy layer dielectric properties were inferred from canopy propagation times (CPT) and were related to canopy water contents (CWC) inferred from phenological measurements (height-mass relationships) and leaf type (narrow or broad). Distinct reflections were correlated with key canopy biophysical parameters. Results demonstrate the usefulness of horn antenna GPR for characterization of vegetation canopy effects, and for subcanopy water content measurements within a well-defined footprint, thereby offering a means for calibration and verification of radar data collected from air- and spaceborne platforms and for use in ground-based environmental and agricultural applications where high temporal resolution is required.

H11B-06 0945h

Application of Radar Profilers in Multi-Sensor Field Campaigns

Kenneth S Gage[1] (303-497-3964; kenneth.S.gage@noaa.gov)

Christopher R Williams[2] (303-497-3829; christopher.r.williams@noaa.gov)

[1]NOAA Aeronomy Laboratory, 325 Broadway, Boulder, CO 80305, United States

[2]CIRES, University of Colorado, Boulder, CO 80309, United States

Precipitation profiling from ground-based radar profilers designed to look vertically have been demonstrated to be useful tools in several field campaigns during the past decade. Beginning with TOGA COARE and most recently during TRMM Ground Validation field campaigns profilers have been utilized to record the vertical structure of diverse precipitating cloud systems. The precipitation profilers are low-powered versions of the boundary layer radars developed within the NOAA Aeronomy Laboratory over a decade ago for wind measurement within tropical boundary layers. In addition to providing a continuous visual record of the evolution of precipitating clouds the profilers provide quantitative information of reflectivities and drop-size distributions that are essential for quantitative precipitation estimation. The profilers are most naturally calibrated by reference to a collocated disdrometer and are in turn useful for providing calibration for scanning radars.

H11C CC: 520 F Monday 0830h

Understanding Flow and Reactive Transport Processes in Sulfide-Bearing Porous Material I

Presiding: **J W Molson,** Ecole Polytechnique**; R Lefebvre,** Institut National de la Recherche Scientifique

H11C-01 0830h INVITED

Predicting the Release of Sulfide Oxidation Products at Mine Waste Sites

David W Blowes[1] (519-888-4878; blowes@uwaterloo.ca); Carol J Ptacek[1] (ptacek@uwaterloo.ca); K Ulrich Mayer[2]; Jeffery G Bain[1]; Michael C Moncur[1]; John L Jambor[2]

[1]Department of Earth Sciences, University of Waterloo, Waterloo, ON N2L 3G1, Canada

[2]Department of Earth and Ocean Sciences, University of British Columbia, Vancouver, BC, Canada

Reactive solute transport models provide sophisticated tools for predicting the magnitude and duration of acid generation and metal release in mine waste disposal facilities. Over the past decade, these models have become increasingly advanced. The ability of reactive solute transport models to simulate integrated biogeochemical and hydrological processes now challenges our ability to characterize these systems on the field and laboratory scale. Application of reactive solute transport models relies on the development of an accurate conceptual model and specification of the chemical, physical and hydrological characteristics of the waste materials. Release of acidic water and dissolved metals from mine waste disposal facilities is controlled by a complex combination of physical, chemical, and biological processes. The oxidation of sulfide minerals is ultimately controlled by the availability of oxygen, which is usually transported in its gaseous form. The reaction between oxygen and sulfide minerals is catalyzed by chemolithotrophic bacteria. The oxidation of individual sulfide minerals occurs at differing rates. Sulfide oxidation reactions release acid, sulfate and dissolved metals. The acid released may be neutralized by reaction with carbonate, hydroxide and aluminosilicate minerals. The metals released may be attenuated by precipitation of secondary minerals, by coprecipitation or by adsorption reactions. Thorough characterization of the waste properties which control gas transport and water flow through the waste materials is required. In addition, a thorough knowledge of the initial composition and mineralogy is required to develop representative estimates of the environmental effects of the waste materials. When sufficient information is available, the results of reactive solute transport simulations show close agreement to measurements made at field sites and in laboratory experiments.

H11C-02 0845h

Measurement and prediction of the oxygen diffusion coefficient in partly saturated media

M Aachib[1] (mamert.mbonimpa@polymtl.ca)

Mamert Mbonimpa[1,2] (mamert.mbonimpa@polymtl.ca)

Michel Aubertin[2] (michel.aubertin@polymtl.ca)

Bruno Bussiere[3] (bruno.bussiere@uqat.ca)

[1]Ecole Hassania, km 7, Route El Jadida, B.P. 8108, Casablanca-Oasis, Morocco

[2]Ecole Polytechnique Montreal, C.P. 6079, Succ. Centre-ville, Montreal, QU H3C, Canada

[3]UQAT, 445 boul. de l'Universite,, Rouyn-Noranda J9X 5E4

Molecular diffusion is an important mechanism for gas transport in various natural and man-made systems. This is particularly the case with soil covers installed on acid generating mine tailings, where oxygen availability has to be controlled. One of the most important roles of such covers is to limit gas flux, which depends on the effective diffusion coefficient De of the cover materials. This paper presents an experimental procedure and results from oxygen diffusion tests performed on different types of materials, at various degrees of saturation. The determination of De in the laboratory from the test data is based on solutions to Fick's laws. The ensuing values of De are compared to values calculated from available models that relate De to basic material properties, including porosity and degree of saturation. Statistical indicators are used to evaluate the accuracy of selected models, individually and on a comparative basis. It is shown that modified versions of the Millington-Quirk and Millington-Shearer models provide De values close to the measured data. A semi-empirical expression, ensuing from these models and measurements, is proposed as a simple means of estimating De.

H11C-03 0900h

Comparison of Different Methods for Determination of Pyrite Oxidation Rate in Wate Rock Pile at Mine Doyon, Quebec, Canada

Ondrej Sracek[1] (srondra@yahoo.com)

Ron Nicholson[2]

Pierre Gélinas[3] (pierre.gelinas@ggl.ulaval.ca)

René Lefebvre[4] ((418) 654-2651; rlefebvre@inrs-ete.uquebec.ca)

[1]Institute of Geological Sciences, Faculty of Science, Masaryk University, Kotláøská 2, 611 37 Brno, Brno, Czech Republic

[2]Department of Earth Sciences, University of Waterloo, Waterloo,, ON, Canada

[3]Département de géologie et de génie géologique, Université Laval, Ste-Foy, QC, Canada

[4]INRS-Eau, Terre et Environnement, Institut national de la recherche scientifique, 880 Chemin Ste-Foy, C.P. 7500, Ste-Foy, QC G1V 4C7, Canada

Mine Doyon is a gold mine located close to Noranda, Québec, Canada. The South waste rock pile contains mostly highly friable sericite schists with pyrite content up to 7 wt percent. Oxidation of pyrite resulted in the production of acid mine drainage with pH values of about 2.0, and sulfate concentrations in pore water above 200 g/L. The waste rock material is characterized by high permeability allowing thermally driven convective supply of oxygen at temperatures reaching up to 67°C close to the slopes of the pile. Several methods for the determination of pyrite oxidation rate (POR) in waste rock have been compared and evaluated. Methods based on data collected in situ such as the interpretation of oxygen concentration profiles in waste rock pile and pyrite concentrations in solid phase were compared with the oxygen consumption method (OCM) in the laboratory. Analytical 1-D solution based on oxygen and temperature profiles in the pile was used for preliminary determination of POR. Analytical modeling results were used as an input for 2-D numerical model using TOUGH AMD. POR values based on pyrite mass balance (PMB) in solid phase were also calculated, assuming that average pyrite content in the deep, almost non-oxidized zone of the pile represents pre-oxidation conditions. Calculations were performed for prismatic columns with 1 m^2 base. An approach based on dissolved sulfate mass balance was not used because of the lack of data from early stage of the pile and the non-conservative behavior of sulfate (precipitation of gypsum and jarosite in the pile). Finally, the oxygen consumption method (OCM) in the laboratory was based on oxygen concentration decline in headspace of closed chamber, where samples of waste rock sprinkled by water were located. Both fresh samples from mining operation and partially weathered samples collected in the pile were used. A range of POR values ($mol(O_2).kg^{-1}.s^{-1}$) were obtained from the various methods. At Site 6 on the slope of the pile, TOP gave $3.93x10^{-9}$ and PMB provided $2.21x10^{-9}$. At Site TBT and Site 7 at the core of the pile, PMB gave respectively $1.76x10^{-9}$ and $2.03x10^{-9}$. Finally, the average rates estimated for the pile are $1.45x10^{-9}$ with TOP and $2.0x10^{-9}$ with PMB. The OCM average rate with fresh material is $6.60x10^{-8}$ whereas weathered material yielded $3.40x10^{-9}$. POR close to slopes were higher than for the core of the pile by a factor of about 3. Results fram PMB also matched the trend, but differences were subtle due to a large uncertainty in estimation of initial pyrite content. Results based on the OCM method in the laboratory were higher for fresh non oxidized material. However, results of OCM with weathered material were consistent with results of other methods. This means that POR values obtained by relatively rough methods like PMB and OCM can be used with acceptable results in a waste rock pile with fast oxygen supply.

H11C-04 0915h INVITED

Hydrologic and Geochemical Transport Processes in Mine Waste Rock

Leslie Smith[1] (604 822 4108; lsmith@eos.ubc.ca)

Joseph Marcoline[1] (jmarcoline@eos.ubc.ca)

Karin Wagner[1] (kwarner@eos.ubc.ca)

Craig Nichol[2] (cnichol@mining.ubc.ca)

Roger Beckie[1] (604 822 6462; rbeckie@eos.ubc.ca)

[1]University of British Columbia, Department of Earth and Ocean Sciences, Vancouver, BC V6T 1Z4, Canada

[2]University of British Columbia, Department of Mining Engineering, Vancouver, BC V6T 1Z4, Canada

A mid-scale waste rock pile experiment (8 m x 8 m x 5 m high) has been ongoing at the Cluff Lake Mine in northern Saskatchewan since 1998. The gneissic waste rock, derived as run-of-mine rock from an open pit, has an average sulfide content of 0.6 wt% S, and yields drainage water with a pH between 3.2 and 4. Waste rock was placed upon a contiguous grid of 16 lysimeters located at the base of the pile. In addition, during construction of the pile, TDR probes and soil water solution samplers were located at various depths beneath the surface of the pile. Results are presented that summarize: (1) the behavior of unsaturated fluid flow and solute transport through heterogeneous waste rock, (2) the hydrologic response to placement of a low-permeability cover on the experimental pile in August 2002, and (3) solute loads released from the waste rock pile. The utility of small-scale laboratory tests to predict metal release at the field scale will also be considered.

H11C-05 0930h

Numerical modeling of soil covers for mine waste rock

Vincent Martin[1] ((514) 340-4711 x4046; vincent.martin@polymtl.ca)

Michel Aubertin[1] ((514) 340-4711 x4046; michel.aubertin@polymtl.ca)

Bruno Bussière[2] (bruno.bussiere@uqat.ca)

Robert Chapuis[1] (robert.chapuis@polymtl.ca)

[1]École Polytechnique de Montréal, C.P. 6079, succursale centre-ville, Montréal, QU H3C 3A7, Canada

[2]Université du Québec en Abitibi-Témiscamingue , Department of Applied Sciences, Université du Québec en Abitibi-Témiscamingue 445 boulevard de l'Université, Rouyn-Noranda, Qu J9X 5E4, Canada

This project consists of studying some key hydrogeological properties of mine waste rocks and cover materials. The main objective was to evaluate the factors that influence flow of water in these materials, and to be able to improve the characterisation methods using numerical models. To do so, field work was completed on a waste rock pile of a mining operation in the southwest United States. Following this, a series of laboratory tests was done on samples of waste rock and of a potential cover material. Using these results, numerical calculations were performed to investigate the unsaturated flow conditions in the pile, for various configurations and properties. The numerical models, which were based on a typical geometry of waste rock dumps, show that the water entry value of the materials can play an important role in the amount of infiltration into the waste rock. The efficiency of covers was also investigated through these calculations. For a semi-arid climate, such as the one observed on the mine site, it is common to use the cover to try to limit water inflow (as opposed to limiting the oxygen flux) into potentially acid generating waste rock. A "Store, Divert and Release" cover (SDR) can typically be used to meet this objective. Different cover configurations have been studied, including a monolayer built with overburden from the mine site, and a multilayered cover composed of a coarse-grained material sandwiched between two layers of fine-grained material. The main results are presented and discussed in the paper.

H11C-06 0945h

Simulating Acid Mine Drainage Through Unsaturated Waste Rock Piles

John W. Molson[1] ((514) 340-4711 x5189; john.molson@polymtl.ca)

Michel Aubertin[1] ((514) 340-4711 x4046; michel.aubertin@polymtl.ca)

Bruno Bussiere[2] ((819) 762-0971; bruno.bussiere@uqat.ca)

[1]Ecole Polytechnique, Dept. of Civil, Geological and Mining Engineering Ecole Polytechnique, Montreal, C.P. 6079 succ. Centre-ville, Montreal, QU H3C 3A7, Canada

[2]Université du Québec en Abitibi-Témiscamingue, Dept. of Applied Sciences 445 University Blvd., Rouyn-Noranda, QU J9X 5E4, Canada

Acid mine drainage (AMD) through unsaturated waste rock piles is numerically simulated to gain insight into the governing physical and chemical processes. The simulations include unsaturated flow, oxygen diffusion, sulphide mineral oxidation, advective-dispersive transport of the oxidation products and pH-dependent geochemical reactions including mineral precipitation and dissolution. The waste pile models are considered as 2D structured porous systems under steady-state flow conditions. The simulations highlight the influence of grain size and moisture content on reaction rates and AMD. Fine-grained sulphide-bearing zones, proposed as internal capillary barriers for example, have a high specific surface area which tends to increase the local sulphide oxidation rate. On the other hand, these zones preferentially retain moisture which reduces the oxygen diffusion coefficient thereby decreasing the reaction rate. The results suggest that where these layers are not fully saturated, sulphide oxidation may continue at a high rate. A sensitivity analysis shows the effect of increasing the background quantity of buffering minerals, and the effect of moisture-dependent diffusion rates and sulphide mineral fractions. Issues related to flow instability and development of preferential flow zones are discussed. These types of simulations can be used to help design waste pile geometries and internal structures (e.g. capillary barriers) which will minimize or control discharge of acidic effluent.

H11C-07 1000h

Modeling Analysis for Characterizing Sulfate Reduction at an Acid Mine Drainage Site

Ashmita Sengupta[1] (ashmita@acad.umass.edu)

David P Ahlfeld[1] (413-545-2681; ahlfeld@ecs.umass.edu)

[1]Dept. of Civil and Environmental Engineering, University of Massachusetts, Amherst, MA 01003, United States

A field site has been established at Davis Mine, an abandoned pyrite mine in rural Rowe, Massachusetts in the United States. At the site, attenuation restricts the extent of AMD in both the groundwater and surface water of the area. Current research is examining the Fe(III) and sulfate reduction along with a complex community of acidophilic and acid-tolerant anaerobic microorganisms. In an effort to interlink the geochemical reduction with the microbial community existing in the site, the role of the Fe(III) and sulfate reducing bacteria is being investigated. Initial experimental data and column studies have shown the presence of sulfate reducing bacteria at the site. A detailed groundwater flow model for the affected site has been developed. A model is currently being developed of the various geochemical and biological processes at Davis Mine for use in distinguishing between sulfate reduction and dilution as they affect observed sulfate attenuation.

H12A CC: 520 C Monday 1030h

Isotope Tracing of Water and Carbon Cycling Processes in Large River Basins II *(joint with B)*

Presiding: **P Aggarwal,** International Atomic Energy Agency**; J J McDonnell,** Oregon State University

H12A-01 1030h INVITED

Stable Carbon Isotope Composition and Dynamics of Particulate Organic Carbon in the Basin of the Ganga-Brahmaputra River

Anne-Marie Aucour[1] (aucour@univ-lyon1.fr)

Christian France-Lanord[2] (cfl@crpg.cnrs-nancy.fr)

Kevin Pedoja[1]

Anne-Catherine Piersson-Wickmann[2]

Simon Sheppard[3] (Simon.Sheppard@ens-lyon.fr)

[1]CNRS UMR 5215, Universite Lyon 1, Villeurbanne Cedex 69622, France

[2]CRPG, CNRS BP20, Vandoeuvre-les-Nancy 54501, France

[3]CNRS UMR 5570, ENSL, Lyon Cedex 07 69364, France

The Ganga-Brahmaputra River ranks first for sediment transport among world rivers, with high erosion rates in the Himalayan range driving the high suspended flux. The organic carbon (OC) burial flux in the Bengal fan has been estimated to be around 1.1 x 10^{12} molC yr^{-1} for the Neogene and could represent about 10% of the global burial flux of OC in continental margins. This stresses the importance of assessing the sources of the organic matter in the Himalayan watersheds and the chemical processing of organic matter on the flood-plain. To follow the dynamics of particulate OC, we used natural ^{13}C-labelling of OC, which is essentially linked to the variable proportion of C3- and C4- plants on the watersheds, together with the mineralogical, chemical and isotopic (ϵ_{Nd}) data of the associated silicates. The stable isotope compositions of OC were measured (1) in bedrocks, soils, and river sediments from an Himalayan watershed (Narayani River, Nepal), (2) in river sediments at several outflows of the range, and (3) in soils and river sediments on the Bangladeshi flood-plain. In the watershed of the Narayani River, the δ^{13}C values of OC range from 26.3 to $22^{o}/_{oo}$ for the bank sediments and from 24.2 to $22^{o}/_{oo}$ for the suspended sediments. They present a narrow range of values around $24^{o}/_{oo}$ at the outflow of the Himalayan range. They are less negative than those of OC in forest soils, hence indicating a significant contribution from the deforested, subtropical zone. On the Bangladesh flood-plain, sediments from the Ganga and Brahmaputra Rivers are enriched in ^{13}C (with δ^{13}C values around $22.5^{o}/_{oo}$) relative to those collected at the range's outflow. This indicates addition of organic matter derived from the mixed C3-C4 biomass on the flood-plain. In sediments of the Ganga and Brahmaputra Rivers, the clay-size fraction is depleted in ^{13}C relative to the bulk sediment. A possible explanation is that the organic matter associated with the clay-size fraction is essentially originating from the Himalayan watersheds.

H12A-02 1045h

Isotopes of dissolved carbon and sulphur in large Canadian river basins: coupled sulphide-carbonate weathering and CO2 release

Kevin Telmer[1] (250 472 4182; ktelmer@uvic.ca)

Joseph Spence[1] (jodys@uvic.ca)

[1]School of Earth and Ocean Sciences, University of Victoria, Victoria, BC V8W 3P6, Canada

Chemical weathering rates and associated CO2 fluxes have been calculated for three major watersheds of the western Canadian Cordillera and for the Ottawa River basin from major element concentrations and d13C of dissolved inorganic carbon (DIC) in river water. Weathering rates and sources determined from major elements are consistent with d13CDIC values (-17.0 to -2.7 permil vpdb) derived from the mixing of three sources of DIC: (i) silicate dissolution by carbonic acid (-17); (ii) carbonate dissolution by carbonic acid (-8.25); and (iii) carbonate dissolution by sulphuric acid derived by oxidative sulphide weathering (+0.5). Isotopes of sulphur and oxygen in the dissolved sulphate ion are used to separate the ammount of sulphate released by sulphide weathering from that contributed by cyclic salts. In the Cordillera, DIC fluxes due to coupled sulphide-carbonate weathering are roughly equivalent to those for silicate weathering. This is less the case for the more geologically mature Ottawa basin. Coupled sulphide-carbonate weathering may therefore provide a long-term source of atmospheric CO2 offsetting silicate weathering CO2 drawdown. The magnitude of this source depends on the tectonic and geological setting.

H12A-03 1100h

Carbon Geochemistry in the St. Lawrence River: Isotopic Approach

Jean-Francois Helie[1] ((514) 987-4080; d150200@er.uqam.ca)

Claude Hillaire-Marcel[1] ((514) 987-4080; chenv@uqam.ca)

[1]GEOTOP-UQAM-McGILL, C.P. 8888 succ. Centre-ville, Montreal, Qc H3C 3P8, Canada

The St. Lawrence River ranks 16^{th} in the world for its mean annual discharge and 13^{th} for its watershed area (~1,000,000 km^2). One of its major particularities lies in the in the size of the Great Lakes, at its head (245,700 km^2). The mean residence time of water in the Great Lakes exceeds 100 years, resulting in relatively buffered physico-chemical properties of the water flowing through the river. The St. Lawrence