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Book Reviews / Critique

REVIEWS

Snow Ecology: An Interdisciplinary Examination of Snow-covered Ecosystems

Edited by H.G. Jones, J.W. Pomeroy, D.A. Walker and R.W. Hoham
Cambridge University Press
40 West 20th Street
New York, New York 10011-4211 USA
2001, 378 p., US$80.00 hardcover
ISBN 0-521-58483-3

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Rejoice in the pleasure it affords us as we ski through fresh powder, or revile it as something to be unendingly shoveled from one's driveway, snow is something those of us living in higher latitudes and altitudes share on a largely seasonal basis. Snow is a major component of the cryosphere (defined as the areas of earth in which water exists seasonally or perennially in solid form, including all snow, ice deposits, and permafrost). It has also long been recognized as important to global climate, hydrology, and human social and economic activities. The focus of this book, however, is to demonstrate that snow cover also forms an important ecosystem, complete with its own physical, chemical, and biological processes that influence its evolution and dynamics as well as those biotic and abiotic communities existing in association with it. Arising out of a meeting in 1993 of the Snow Ecology Working Group of the International Commission of Snow and Ice (part of the International Association of Hydrological Sciences), and presented in seven chapters written by an international array of 15 researchers, *Snow Ecology* provides the reader with an interesting, although not exhaustive review of the subject matter.

The opening chapter, "Snow Cover and the Climate System," discusses the spatial and temporal distribution of snow, the synoptic and climatic feedback mechanisms related to snow cover (and their relevance to GCMs), and various direct and remote sensing methodologies used to measure snow characteristics. This last subject highlights the lack of long-term homogeneous global snow records, problems in inter-study comparisons, and the many difficulties encountered in trying to measure snow properties on local and global scales. It is unfortunate that the authors did not indicate that many of the snow cover data sets and research centres discussed are available online (*i.e.*, the Canadian snow and ice research group CRYSYS http://www.crysys.uwaterloo.ca; the snow and ice program at NOAA http://www.ssd.noaa.gov/PS/SNOW; or the United States National Snow and Ice Data Center http://www-nsidc.colorado.edu). I also reflected that following last winter's record 180 cm snowpack (>500 cm actual snowfall), those living in St. John's, Newfoundland would appreciate such geographically sweeping statements as "Up to 80 cm of snow is reported in winters in Canada..." (p. 14). Such vagaries, however, may well reflect the inherent problems in discussing a material that is seasonally, temporally, and spatially variable. Thus, while this chapter is perhaps a somewhat curious beginning to a book focussed on snow ecology, it serves to illustrate the important interdisciplinary nature of such studies, and how snow cover and its climatological links can form an important foundation to diverse ecological studies.

Chapter two, "Physical Properties of Snow," addresses the multi-phase physical properties of snow, its role in energy exchange and mass balance, the structure and metamorphosis of snow packs over time, and the nature of snow accumulation and redistribution in space, time, and under different vegetational architectures. Attention is drawn to how these affect life in the sub-, intra-, and supranivian environments. This is an excellent review and will serve as a useful introduction and reference to all manner of snow studies.

Chapter three, "The Chemistry of Snow: Processes and Nutrient Cycling," presents a thoroughly interesting review of the scavenging of chemical species during atmospheric snow formation, the chemical composition and metamorphosis of wet and dry snowpacks, the gaseous and chemical interaction between snowpacks and underlying soil and organic matter (accounting for up to 20% annual CO_2 and 50% N_2O emissions), a discussion of the significance of snow chemistry and resultant melt to ecosystems (*i.e.*, acid shock during the spring freshet), and an introduction to snowpack microbial activity and its role in nitrogen fluctuations (an often limiting nutrient in many ecosystems). Snow is presented as a dynamic reservoir of chemical species and a significant component of biogeochemical cycling of nutrients and gases.

Chapter four, "Microbial Ecology of Snow and Freshwater Ice with Emphasis on Snow Algae," quickly disperses any notion that snowpacks are pristine, sterile environments. This chapter provides a review of global snow and ice microbial literature, and focusses largely on the physiological adaptations, life cycles, and possible origins of psychrophilic (snow) algae. It is shown that the water film surrounding ice crystal lattices within snowpacks can support both microbial life (bacteria, algae, and fungi) and the grazers that feed on them (protozoa and rotifers), and that both groups of organisms take advantage of unique chemical environments. The authors demonstrate the importance of snow algae to overall productivity and biogeochemical cycling of nutrients, the bioaccumulation of heavy metals, and the snow algal role in regulating snowmelt. It was an interesting aside to discover that the fashion-bedecked skiing culture may themselves contribute to the inoculation of ski slopes and spread of an algae culture, *Chloromonas* sp.-B: an alga specific to artificial snow (which can readily survive summers on basement-stored skis and snowboards).

Chapter five, "The Effect of Snow Cover on Small Animals," initially discusses invertebrate nival fauna, including iceworms, spiders, mites, beetles, flies, and other insects. Topics include their abundance and geographic distribution, physiological and morphological adaptations, and various life and food cycles. This is followed by a discussion of the ecology and physiology of subnivean vertebrates, focussing on lemmings and shrews, and their adaptation to this insulated environment. These animals form part of an elaborate food chain that includes both nival flora and fauna, as well as higher tropic animals existing in the supranival environment. It is also pointed out that burrowing activities can be tied to regulation of subnival CO_2 concentrations, and therefore an understanding of the ecology of these animals is relevant to carbon budget and other snow geochemical studies.

Chapter six, "Snow-Vegetation Interactions in Tundra Environments," discusses the broad relationships between snow and vegetation type, distribution, and structure. The authors demonstrate the role snow plays in influencing various vegetational communities along altitudinal transects and, in particular within the tundra environment, where late-lying snowpacks can both inhibit and promote vegetational growth. This chapter concludes with a brief outline of experiments that assess the effects of altered snow regimes on vegetational ecosystems. The importance of such work is clearly directed toward future global climate change scenarios.

Chapter seven, "Tree-Ring Dating of Past Snow Regimes," presents the specialized application of dendrochronology (the study of tree rings) to assess various physiological and vegetational changes in trees related to abrasion by blowing snow, freezing, and changes in snowpack regime. While many may be more familiar with deformed or krummholtz trees in alpine tree line localities, this chapter provides an interesting presentation of snow-abraded and misshapen tree studies in the Forest-Tundra biome of north-central Quebec.

Overall I found this book to be an interesting and informative read on a subject matter of increasing importance to the broader issue of global climate change. Much of the material presented draws obvious connections and interrelationships among the individual areas of study, strengthening the notion of snow as an ecosystem. Small complaints include: the inconsistent use and or defining of terminology (*e.g.*, snowpack, snowbed), the variable quality of illustrations, and the inclusion of four-colour plates, which, while useful, are not drawn to the reader's attention in their respective chapters, where the figures are first presented in black and white (yet nonetheless have captions describing zones according to colour-indexed scales). The literature review in each chapter is extensive; however, there remains a geographical bias to the northern hemisphere, and particularly North American sites. Most references are from papers prior to 1997 (although there are occasionally more recent publications included), suggesting that this volume has been some time in production. While this shouldn't lessen the overall importance of this work, it may not accurately reflect the increased attention and importance being paid to global snow research today (as evident by the profusion of snow and cryosphere research Web sites and data sets in existence). Although this book is unlikely to become the focus textbook of a single course, it will no doubt serve as a very useful review and reference for those engaged in cryospheric studies.

The Nature and Tectonic Significance of Fault Zone Weakening

Edited by R.E. Holdsworth, R.A. Strachan, J.F. Magloughlin, and R.J. Knipe
Geological Society, London,
Special Publication 186,
342 p., 2001
Geological Society Publishing House
Unit 7, Brassmill Enterprise Centre
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This Special Publication of the Geological Society of London is one of the latest in a long series of volumes that generally derive from conferences hosted in the UK. This volume stems from a March 2000 conference held under the joint auspices of the Geological Society of London, the Geological Society of America, and InterRidge (an international academic initiative concerned with mid-ocean ridge studies). As with most of these publications, Volume 186 contains an eclectic but well-balanced mix of papers. These 18 contributions range from experimental and numerical modelling studies to field studies spanning microstructural to crustal and lithospheric scales.

The stage is set by an introductory paper by E.H. Rutter, R.E. Holdsworth, and R.J. Knipe who review concepts of fault-zone weakening in both the upper crustal brittle-frictional regime, and the lower crustal to upper mantle plastic-viscous regime. Rutter *et al.* conclude that our general understanding of fault and shear zone processes is relatively poor and even speculative, strongly limiting our ability to predict earthquakes, for example. The remaining 17 contributions are grouped by the editors into four sections.

The first section, "Insights from Neotectonic Settings, Deformation

Experiments and Modelling Studies," consists of four papers.

1) J. Townend and M.D. Zoback, examine the San Andreas Fault (SAF) system using earthquake focal mechanism solutions to constrain its frictional properties. These solutions indicate that the greatest horizontal compressive stress is oriented at high angles to the SAF throughout southern California, implying that the SAF system has a frictional strength much lower than anticipated for almost any rock type under near-hydrostatic pore pressures, and so low that there is no discernible shear-heating anomaly. The actual mechanism producing the low frictional strength is unclear, however.
2) A. Kopf examines a suite of recent Ocean Drilling Program (ODP Leg 180 – Woodlark Basin, south of the Salomon Sea) shallow drill core samples (all less than 0.5 km below the sea floor) through an active low-angle detachment fault. Physical measurements pertinent to mechanical strength concentrated on permeability with respect to orientations of rock fabric and deformation structures. The detachment and associated splay faults are seen to be zones of enhanced permeability (and hence fluid migration) in the fault plane direction. Mudstone permeability across the detachment fault can vary over several orders of magnitude, whereas the measured anisotropy of permeability varied by one order of magnitude (flow parallel to the detachment >> flow perpendicular to it). Multi-phase mineralization suggests repeated cycles of sealing by authigenic precipitates, fluid pressure build-up, brittle failure, and a phase of enhanced fluid flow.
3) Main, K. Mair, O. Kwon, S. Elphick, and B. Ngwenya undertake a review of experimental studies of deformation bands in porous sandstones. Deformation bands, which typically form in porous, clay-poor sandstones within a few kilometres of Earth's surface, can strongly influence the magnitude and degree of anisotropy of permeability. They form as a consequence of strongly coupled changes in fault strength due to variation in physical properties (*e.g.*, fault gouge), hydraulic properties (*e.g.*, pore pressure), and chemical properties (*e.g.*, cementation). Main *et al.* infer a cyclical sequence of property variation, involving both positive and negative feedback, for deformation band development. The combination of chemical and physical sealing rates, observed or inferred from experiments, can account for the six orders of magnitude reduction in permeability in deformation bands observed in natural exposures.
4) K.P. Furlong, S.D. Sheaffer, and R. Malservisi examine deformation within oceanic transform fault zones using a numerical modelling approach. Their sophisticated 3-D coupled thermal-mechanical finite element model allows them to address some of the complexities of thermal and mechanical feedback controls on rheologies (both brittle and temperature-dependent ductile). Model results indicate that the plate boundary at mantle depths is offset from the crustal transform fault zone, such that the mantle lithosphere of the older, cooler plate extends toward and beneath the crust of the younger plate. This geometry is a consequence of lateral heat conduction, whereby young near-ridge material is cooled due to its proximity to cooler, older material on the opposite side of the transform. Furlong *et al.*'s model results provide constraints on the mechanics of recently documented extensional core-complex style deformation at the inside corners of many ridge-transform intersections, and on the stability limits of age offsets across transforms as a function of plate velocity.

Four contributions comprise the second section, "Insights from Natural Fault Rocks."

1) L.W. Warr and S. Cox examine weakening mechanisms along the Alpine Fault in New Zealand. They suggest that the formation of hydrous clay minerals, through infiltration of aqueous fluids within active fault zones, can significantly weaken these zones by influencing fluid motion and storage. Using X-ray diffraction and transmission electron microscopy techniques, Warr and Cox examined 53 samples of clay-bearing mylonite, cataclasite, and gouge gathered at three locations along the Alpine Fault. Their observations suggest three modes of deformation and alteration of these materials: 1) initial strain-hardening under relatively deep, anhydrous conditions; 2) reaction weakening with formation of Mg-chlorite at temperatures below 320°C; and 3) continued reaction weakening below 120°C by growth of swelling clays. The mechanically weak and relatively impermeable clay-rich smears may enable generation of high pore-fluid pressures during faulting, greatly reducing the effective stress. Warr and Cox envisage a complex interplay between faulting, fluid migration, and hydrous clay mineral transformations that are continually repeated during fault evolution.
2) Y. Yan, B.A. Van der Pluijm, and D.R. Peacor focus on clay transformation and fault weakening in the gouge zone and immediate footwall of the Lewis Thrust in Alberta, Canada, using X-ray diffraction, X-ray goniometry, scanning electron microscopy, and transmission and analytical electron microscopy. Over a distance of <10 m footwall samples of shales and bentonites show an increase in illite at the expense of smectite, with the transition accommodated by dissolution-neocrystallization. The intensity of clay preferred orientation decreases with increasing illitization, a relationship interpreted by Yan *et al.* to indicate that faulting was the cause of the mineral transformations and development of secondary porosity. They infer that a positive feedback relationship was established, whereby illitization and associated fluid release and porosity increase led to further faulting in the clay gouge, leading in turn to enhanced weakening of the fault zone.
3) G. Mitra and Z. Ismat discuss observations of grain-scale microfracturing in Proterozoic quartzites from the Canyon Mountains in the Sevier belt of central Utah, United States. They provide a brief review of qualitative fault zone models, including discussion of fault zone reactivation, followed by a description of the structural setting of the Canyon Mountains. Samples examined in the study were taken from and immediately adjacent to a fault zone on the hinterland flank of a kilometre-scale Sevier-age antiformal stack, reactivated as a normal fault during Basin and Range extension. Microstructures were studied in thin-section using polarized and dark-field optical microscopy, and scanning electron microscopy. This

allowed the recognition of three generations of microcracks in the reactivated fault zone. Though microcrack density generally decreases away from the fault, density variation adjacent to reactivated zones may be much more irregular.

4) K. Steffen, J. Selverstone, and A. Brearly examine microstructural and metamorphic evidence for a succession of weakening and strengthening episodes in the Greiner deep-crustal shear zone in the Austrian Alps. Stage I involved strain-softening through grain-size reduction facilitated by fluid-assisted grain boundary diffusion creep in plagioclase-rich horizons. Stage II involved strengthening due to rapid growth of hornblende crystals "locking" the shear zone and shifting ductile strain to weaker horizons. Stage III involved softening caused by replacement of the large hornblende crystals by biotite in some horizons. Subsequent strain was concentrated in the biotite-rich units. The results of Steffen *et al.* have implications for other deep-seated shear zones displaying Garbenschiefer texture (large hornblende porphyroblasts).

"Geometric Controls and Fault System Evolution," the third section of the volume, consists of three papers focusing on the fundamental influence on strain localization and fault growth of factors such as fault size, connectivity, position and orientation.

1) J.J. Walsh, C. Childs, V. Meyer, T. Manzocchi, J. Imber, A. Nicol, G. Tuckwell, W.R. Bailey, C.G. Bonson, J. Watterson, P.A. Nell, and J. Strand present kinematic analyses of normal fault systems imaged by marine seismic reflection data, and compare these observations to numerical displacement models. Using data from the North Sea (Inner Moray Firth) and the Timor Sea, they derive fault growth histories from observation of thickness and displacement variations within overlying syn-faulting sedimentary successions. The principal relationships established by these fault histories are 1) strain localization onto larger faults and optimally placed smaller faults, and 2) correlations between fault size and displacement rate. These relationships are examined using a discrete element modelling code, where the elastic properties of and bond strengths between spherical particle elements are appropriate to the bulk strength of typical fine-grained sandstone. A specified volume of material under confining pressure is modelled, with predefined vertical discontinuities representing fault planes. The resultant strain histories are strongly dependent upon the geometric properties of the fault system, and only weakly dependent upon the strength of the faults.

2) S.F. Wojtal uses observations of shear surfaces in fault zones in the Appalachians of western Newfoundland, Canada, that possess monoclinic symmetry, to infer that initiation of shear surfaces in asymmetric arrays may be related to the velocity gradient tensor, which possesses a consistent symmetry in a steady, non-coaxial shearing flow. Upon casual inspection, such arrays of shear surfaces are commonly interpreted as "Reidel shears." However, Reidel shears possess an orthorhombic symmetry, rather than monoclinic, and are therefore incompatible with the asymmetry observed in melange of the Humber Arm Allochthon.

3) L.E. Beacom, R.E. Holdsworth, K.J.W. McCaffrey, and T.B. Anderson consider how pre-existing heterogeneities may influence fracture zone development during periods of basement reactivation in the Paleoproterozoic Lewisian Complex, northwest Scotland. Geometric and orientation field data are used to test quantitatively the degree of influence, on patterns of younger fault development, of lithology and pre-existing structural geometry along laterally persistent basement faults. Beacom *et al.* conclude that reactivation of pre-existing anisotropies in the basement gneisses significantly control brittle fault development and growth in the upper crust.

The fourth and final section, "Insights from Lithosphere- to Crustal-Scale Fault Zones," presents a series of six case studies involving long-term reactivation of faults and shear zones.

1) B. Tikoff, P. Kelso, C. Manduca, M.J. Markley, and J. Gillaspy consider reactivation along an interpreted ancient plate boundary, represented by the Salmon River suture zone in Idaho, United States. This structural/tectonic feature, considered to be the Early Cretaceous suture between the North American Craton and Cordilleran accreted terranes, was reactivated in Late Cretaceous time (the western Idaho shear zone) and in Miocene time (Basin and Range extension). Tikoff *et al.* draw two main conclusions: 1) the Early Cretaceous accretion event created a persistent "lithospheric flaw", where the mantle lithosphere was not "healed" during orogenesis, and 2) the curious paucity of recognizable strike-slip plate and terrane boundaries may reflect the ease with which such features are subsequently reactivated and structurally overprinted. They also provide an interesting discussion of the role of mechanical anisotropy on admissible stress states for reactivation.

2) C. Simpson, S.J. Whitmeyer, D.G. De Paor, L.P. Gromet, R. Miro, M.A. Krol, and H. Short examine sequential ductile to brittle reactivation in the Sierras Pampeanas of Argentina, where metamorphic and plutonic basement rocks and sedimentary and plutonic cover sequences have been involved in multiple episodes of deformation. Map geometries, outcrop-scale fabrics, and microstructural studies are used to reconstruct a series of early high-strain contractional events that are broadly decreasing in metamorphic grade, culminating in semi-brittle thrust reactivation. Many of these fault and shear zones were reactivated as brittle extensional faults in Carboniferous to Cretaceous time, associated with and leading to the development of the Carboniferous-Permian Paganzo basin and a series of Triassic through Cretaceous pull-apart basins. Mid- to Late Tertiary to Recent contractional brittle fault reactivation along and adjacent to basin margins (basin inversion) is accompanied by locally large along-strike extension. Simpson *et al.* propose that both the contractional and extensional phases of reactivation resulted in creation of "short-cut" faults, consistent with Andersonian fault theory.

3) R.D. Hatcher Jr. describes reactivation events interpreted along the Paleozoic Brevard fault zone in the southern Appalachians, United States. Hatcher provides a review of interpretations of the Brevard zone, which has seen reactivation during the late Paleozoic

Alleghanian orogeny, which overprinted an earlier, middle Paleozoic (Acadian) fabric.

4) E. Tavarnelli, F. A. Decandia, P. Renda, M. Tramutoli, E. Gueguen, and M. Alberti discuss reactivation in the arcuate Apennine-Maghrebide fold-and-thrust belt, Italy, focusing on two major, long-lived, repeatedly reactivated, fault zones: 1) the Valnerina Line, in the central Apennines, and 2) the Gratteri-Mount Mufara Line, in central-northern Sicily. Tavarnelli *et al.* describe the structural histories of each of these features, within which they have recognized three sequential stages corresponding to Late Triassic-Eocene, Oligocene-Early Miocene, and Late Miocene-Pliocene time intervals. Stage I corresponds to opening and closing of the Tethys Ocean, whereas Stages II and III encompass the evolution of the Apennine-Maghrebide fold-and-thrust belt. Tavarnelli *et al.* challenge the view that this orogenic system is thin-skinned, suggesting instead that deep, repeatedly reactivated, Mesozoic fault zones cutting through pre-Triassic basement are the principal control on Apennine-Maghrebide belt structure.

5) C.J. Talbot reviews weak fault zones described in and bordering Precambrian rocks in Sweden, with a view to understanding those processes that made these faults weak. For these specific cases, Talbot defines weak zones as those displaying post-glacial reactivation of old shear zones. Strain analyses of shear zones indicate long-lived histories, with superimposed ductile, semi-ductile, and brittle structures, with varying kinematics. Repeated reactivation has generated thick seams of cataclasites, in which pore fluids are envisaged to weaken the fault zones, permitting almost aseismic frictional sliding.

6) M.R. Handy, A. Mulch, M. Rosenau, and C.L. Rosenberg provide a synthesis and review of relationships between fault zones and melts, and provide solutions to a set of outstanding questions regarding the roles of crustal melts in weakening, strengthening, and physically differentiating the continental crust. Transport and emplacement of crustal melts is affected by two first-order rheological-mechanical transitions: 1) the brittle-ductile ("solid-state viscous flow" of Handy *et al.*) transition, and 2) the transition from mylonitic (ductile) flow to anatectic flow. The latter transition corresponds to the onset of crustal melting (compositionally dependent). Given the many-orders-of-magnitude difference in strength between melts and host rocks, and the transient nature of the presence and influence of melts, characterizing the bulk rheology of anatectic rock systems is very difficult, though Handy *et al.* attempt to place a reasonable upper limit on strength (they estimate a maximum differential stress between 5-10 MPa). Three speculative modes of syntectonic melt flow in shear zones are proposed, dynamically dependent upon permeability parallel to the shear zone boundary and on shear strain. These modes are represented by variations in micro- and meso-structures. Handy *et al.* provide an extended, thought-provoking discussion on thermomechanical processes in crustal-scale shear zones, using a variety of well-studied examples.

As with other volumes in the Geological Society of London Special Publication series, the printing and binding quality is very high, with crisp figures, sharp and well-contrast-balanced photographs, good colour reproduction (Main *et al.*, Furlong *et al.*, Walsh *et al.*, and Hatcher), very attractive typesetting and layout, and robust binding and hard cover.

The list price, at US$117, is fairly hefty, sufficiently so that the only individuals likely to purchase this volume will be experts in the field. The price for AAPG members is significantly better, US$70, but still substantial. Most libraries have standing purchase orders with the Geological Society for the Special Publication series, and I strongly encourage anyone interested in fault zone processes and reactivation to thumb through this well-balanced volume.

The Age of Dinosaurs in Russia and Mongolia

Edited by M.J. Benton, M.A. Shishkin, D.M. Unwin, and E.N. Kurochkin
Cambridge University Press
2000, 672 p., US$110.00 hardcover

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Mongolia may be the most productive area for Mesozoic vertebrates in the world, rivalled (or surpassed) only by Western Canada. Much crucial work on these animals has languished in undeserved neglect by English-speaking authors. The editors of *The Age of Dinosaurs in Russia and Mongolia* have sought to rectify this situation, to allow the Western world to rediscover some of the "lost" specimens described from Asia and European Russia. In a literal sense, this negative trend is accelerating as entrepreneurs tour delicate display specimens around the world, and some fossils disappear into the black market (*Globe and Mail*, 6 February 2002). The book is therefore a valuable compilation of important research, and a timely reminder of Russia's contributions to knowledge of our fossil heritage.

The editors adopt uniform sets of conventions as a bridge between English and Russian researchers, a difficult enterprise in which they do not wholly succeed. When Russian concepts are out of phase with international stratigraphic systems, they retain Russian terms (such as "gorizont" and "svita") to maintain consistency with the literature, and avoid ambiguities. However, success is mixed for translation from Cyrillic. The editors refreshingly use an apostrophe for the soft sign, but use the letter "e" to represent the sounds "eh," "yeh," and "yo." More crucially for professionals, their reworking of place, personal, and journal names sometimes conflicts with earlier translations of familiar primary literature.

Although not explicitly subdivided as such, the 54 authors' contributions are arranged in approximate chronological order from the Permian to the Cretaceous. Chapters 1-10 deal with Permian and Triassic faunas, biostratigraphy, and the history of Eastern European discoveries. A transitional couplet (Chapters 14 and 15) relates the story of expeditions to Central Asia from the 1920s to the present. Two complementary chapters then describe the Cretaceous stratigraphy of Mongolia from Russian and Western points of view. The remainder of the book follows an arc of zoological descriptions from marine (Chapter 11) and obligately sprawling tetrapods (Chapters 16-19), to archosaurs (Chapters 20-28) and mammals (Chapters 29 and 30).

There is a great deal of disparity between engaging chapters and those that dryly list taxa and their diagnostic features. Respective authors present pareiasaurs, turtles, some Mesozoic amphibians, mammals, and sauropods with varying degrees of tedium. Conversely, other authors explore interesting aspects of biostratigraphy, palaeoenvironments, faunal correlations, and evolution. Groups treated with this depth include Permian amniotes, Cretaceous lizards, pachycephalosaurs and ceratopsians, theropods, and pterosaurs. One chapter's consideration of mammal palaeoneurology is fascinating. Temnospondyl and anthracosaur chapters describe morphology and even habits of these less familiar groups, a practice that would have enlivened the systematic recitations pervasive in much of the book.

The chapters on dinosaurs will be of most interest and familiarity to the general public. Currie deftly parses differences among contemporaneous oviraptorosaurs, and convincingly argues that Asian tyrannosaurids have been oversplit based on developmental patterns. Maryanska concisely describes the three Mongolian sauropod genera. Norman and Sues provide a comprehensive survey of Asian ornithopods, and suggest that further study of these dinosaurs is necessary to understand their distribution in the Northern Hemisphere. Sereno surpasses the book's mandate with a revised phylogeny of pachycephalosaurs and ceratopsians, and includes an interesting discussion of evolutionary trends in these dinosaurs. Tumanova describes Mongolian ankylosaurs, including a basal form from the Early Cretaceous, and provides a possible evolutionary sequence within the ankylosaur lineage.

Figures are of varying quality, but are mostly adequate. Photographs in Chapter 3 show almost painfully exquisite preservation of Russian temnospondyls, and Sereno's chapter benefits from amazing drawings by Carol Abraszinskas. Excellent photographs of Central Asian mammal specimens are confusingly organized by locality and not taxon. Sometimes figures do not depict diagnostic features; sauropod and crocodilian teeth are described for given taxa, yet apparently toothless specimens are figured. Most figures were reproduced line drawings. Maryanska uses a redrawn *Opisthocoelicaudia* figure in which the unfortunate sauropod is walking with its hands turned sideways. Life restorations are few; an early illustration of a vivid gorgonopsian (and cartoonish pareiasaurs) graces the first chapter, and one multituberculate turns up in full fur.

Maps and tables are generally useful. Most chapters include locality maps. These are often modifications of one template, which provides consistency from chapter to chapter. However, authors rarely refer to the maps in their systematic or biogeographical surveys. Many tables reference primary literature, a feature very useful to specialists, if less so to the general reader. Triassic fauna tables are both taxonomic- and biostratigraphically based, making it easy to find different kinds of information quickly. Norman and Sues helpfully summarize in table format their findings on the taxonomic validity of Asian ornithopods.

Differences in phylogenetic training between Russian and Western workers are occasionally stark. Sereno explicitly structures his taxonomic definitions, and he, Lee, and Modesto and Rybczynski offer testable phylogenies with character matrices. In contrast, evolutionary systematic thinking crops up among the Russian authors, in the form of innocuous and probably correct ancestor identifications, but irritatingly in Kurochkin's bird chapter. He astoundingly channels Dollo's law of evolutionary irreversibility, outmoded a century ago, to posit that only enantiornithine birds may have evolved from Mesozoic theropods.

Despite occasional caveats, as graduate students in paleontology we found the book valuable as a reference. Specialists will get the most out of chapters targeted to their subject of interest, but non-experts will usually be able to glean helpful information. For example, chapters on the sedimentary geology and palaeoenvironments of the Mongolian Cretaceous were decipherable to the non-geologist, and provided context for subsequent discussions of Central Asian faunas.

The question arises as to the intended audience for this reference. We recommend the book for professional tetrapod paleontologists, as well as advanced students. We certainly would have purchased it as undergraduates, but the rather stiff price of US$110 is a bit overwhelming, even for those jaded to usurious charges for textbooks. We are currently scrimping, however, so that the one who loses the scrap over the review copy can purchase his/her own.

Climate Change Impacts on the United States: The Potential Consequences of Climate Variability and Change

National Assessment Synthesis Team of the United States Global Change Research Program
May 2001, 624 p., hardcover, US$39.95
ISBN 0-521-00075-0

Reviewed by John J. Clague
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This report summarizes what is known about the potential consequences of climate variability and change for the United States in the 21st century. It was prepared under the leadership of the National Assessment Synthesis Team (NAST), an advisory committee of experts drawn from governments, universities, industry, and non-governmental organizations. NAST was established on the basis of legislation enacted in the

United States in 1990 to help the U.S. Global Change Research Program achieve its mandate. The report was delivered to Congress by Bill Clinton in one of his final acts as President and has collected dust ever since, not surprising given the low priority Bush, Cheney, and others in the United States administration attach to climate warming.

The assessment report is both comprehensive and balanced. It includes contributions from dozens of the world's foremost experts in meteorology, climatology, oceanography, and other fields of science. It was reviewed by more than 300 scientific and technical experts, and the review process was overseen by a panel of experts convened by the President's Committee of Advisors on Science and Technology. The findings are based on a synthesis of historical data, model projections, and published scientific research, which demonstrate beyond a shadow of doubt that global warming is a *fait accompli* that must be reckoned with and recognized as a bonafide threat.

The report fully acknowledges the uncertainties involved in predicting future climate. It presents scenarios (plausible alternative futures), rather than specific predictions or forecasts. The primary resources for the assessment are differing projections of future climate change from the Hadley Centre in the United Kingdom and the Canadian Centre for Climate Modeling and Analysis (ah, Canadian content!). For some aspects of climate, the Hadley and Canadian models agree on the types of changes to be expected. For example, both models suggest that climate will become warmer and precipitation will more likely come in heavy and extreme events. For some other aspects of climate, however, the model results differ. For example, the Canadian model projects more extensive and frequent drought in the United States, whereas the Hadley model does not. The Canadian model suggests a drier south-eastern United States. in the 21st century, whereas the Hadley model suggests a wetter one.

To acknowledge these uncertainties, the maps in the report are derived from the two climate model scenarios. In most cases, there are three maps: one shows average conditions based on actual observations from 1961 to 1990; the other two are generated by the Hadley and Canadian model scenarios. Maps and other figures in the main body of the report are black-and-white, but they are reproduced in full colour in an Appendix at the end of the report. Presumably, this was done to reduce the cost of the report and thus increase its market.

The report is organized both by regions and sectors. Nine chapters focus on potential climate change impacts on regions: the Northeast, Southeast, Midwest, Great Plains, West, Pacific Northwest, Alaska, Islands, and Native People and Homelands. Five chapters focus on impacts on agriculture, water, human health, coastal areas and marine resources, and forests.

The key conclusions of the report are:

1) **Increased warming.** Temperatures in the United States will rise 3-5°C on average in the next 100 years.
2) **Differing regional impacts.** Climate change will vary widely across the United States. Temperature increases will vary from one region to the next. Heavy and extreme precipitation events are likely to become more frequent, yet some regions will become drier.
3) **Vulnerable ecosystems.** Many ecosystems are highly vulnerable to the projected rate and magnitude of climate change. A few are likely to disappear entirely in some areas. Economic output lost through the disappearance or fragmentation of ecosystems will probably be costly or impossible to replace.
4) **Widespread water concerns.** Drought is an important concern in every region, and floods and water quality are concerns in many regions.
5) **Secure food supply.** At the national level, the agriculture sector is likely to be able to adapt to climate change. Crop productivity in the United States probably will increase over the next several decades, but the gains will not be uniform across the country.
6) **Forest growth.** Forest productivity is likely to increase over the next several decades in some areas as trees respond to higher carbon dioxide levels. Over the longer term, changes in processes such as fire, insects, droughts, and disease will possibly decrease forest productivity. Climate change will to cause long-term shifts in the distribution of tree species.
7) **Increased damage in coastal and permafrost areas.** Climate change and the resulting rise in sea level are likely to exacerbate threats to infrastructure in Alaska and low-lying coastal areas.
8) **Adaptation determines health outcomes.** A variety of negative health impacts is possible from climate change, including water-borne diseases, heat stress, air pollution, extreme weather events, and diseases transmitted by insects and rodents. However, health and other community services are likely to protect much of the population of the United States.
9) **Other stresses magnified by climate change.** Climate change will magnify the impacts of other stresses, such as air and water pollution and habitat destruction due to development.
10) **Uncertainties remain and surprises are to be expected.** Significant uncertainties remain in the science underlying climate change and its impacts. Further research is required to better estimate societal and ecosystem impacts and to provide the public with useful, reliable information about options for adaptation. However, it is likely that some aspects and impacts of climate change will be totally unanticipated as complex systems respond to climate change in unforeseeable ways.

One interesting aspect of the report is that it focusses almost exclusively on adaptation as the main societal response to climate change. After identifying potential impacts, the report identifies adaptation measures for each region and sector. The other principal societal response to climate change, which is not dealt with in the report, is mitigation, *i.e.*, measures to reduce greenhouse gas emissions. In fairness to the authors, the report acknowledges that "both mitigation and adaptation measures are necessary elements of a coherent and integrated response to climate change," but the decision not to deal with mitigation seems odd, and I cannot help but wonder if political considerations came into play here. Perhaps this reflects not so much politics as realism, as there appears to be no way that either Americans or Canadians are going to reduce their use of fossil fuels in the near future. To put it bluntly, we are hooked on oil!

This book is not a "page turner," but if you are looking for the most up-to-date reference on the potential effects of global warming on the United States, this is it. It's a pity that Canada has not produced a similar document.

Looking into the Earth: An Introduction to Geological Geophysics

Alan E. Mussett and M. Aftab Khan
Cambridge University Press
2000, 470 p.

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I have always been impressed with the quality (and excellent value!) of publications from Cambridge University Press. This book, certain to be very well-received for undergraduate courses, is no exception. My first impression was positive: this volume has an attractive format and layout, numerous inset "boxes" providing additional detail and focus, sharp figures, and judicious use of colour. This first impression was only reinforced when I dug into the book.

As Mussett and Khan imply in the Preface, geologists have traditionally been relatively unfamiliar with physics and the associated mathematics. Consequently, many geologists tend either to ignore geophysics or, perhaps worse, to accept the conclusions of geophysical studies without appreciating the qualifications behind those conclusions. This latter tendency is, in Mussett and Khan's words, "to treat the geophysicist as some sort of magician." As there is a fine line between magicians and witches, understanding and appreciating the limitations as well as the power of geophysics become essential geological skills. Mussett and Khan set out to provide this level of basic knowledge to geologists, removing the mystique, and expanding understanding.

At first glance, the term "geological geophysics" appears awkward if not somewhat redundant. However, as Mussett and Khan explain, this term is used for approaches whereby geophysics is used as an aid to geological interpretation, in contrast to "pure geophysics," such as studying how the Earth's magnetic field is produced, and "observational geophysics," where the Earth is viewed as a giant laboratory. They reinforce the point that geophysical methods are the only ones that can truly "look" into the Earth's interior, remotely examining buried bodies and structures. This provides the geologist with controls on the third dimension that traditional geological approaches generally cannot.

Following the introductory chapter, "Introducing Geophysics and This Book," the book is divided into two parts. Part I explains the various geophysical methods, including basic physical principles. Part II describes a number of applications of geophysics, illustrated with case studies. These are in turn divided into Subparts, Chapters, Sections, and Subsections. The breadth of material covered is perhaps best conveyed here by listing headings down to chapter level:

Part I, Geophysical Methods
- *Subpart I.1, Data Acquisition and Processing*
- Chapter 2, Data Acquisition and Reduction: Carrying out a Geophysical Survey
- Chapter 3, Data Processing: Getting More Information from the Data
- *Subpart I.2, Seismology*
- Chapter 4, Global Seismology and Seismic Waves
- Chapter 5, Earthquakes and Seismotectonics
- Chapter 6, Refraction Seismology
- Chapter 7, Reflection Seismology
- *Subpart I.3, Gravity*
- Chapter 8, Gravity on a Small Scale
- Chapter 9, Large-Scale Gravity and Isostasy
- *Subpart I.4, Magnetism*
- Chapter 10, Palaeomagnetism and Mineral Magnetism
- Chapter 11, Magnetic Surveying
- Subpart I.5, Electrical
- Chapter 12, Resistivity Methods
- Chapter 13, Induce Polarisation and Self-Potential
- Chapter 14, Electromagnetic Methods
- *Subpart I.6, Radioactivity*
- Chapter 15, The Ages of Rocky and Minerals: Radiometric Dating
- Chapter 16, Radioactive Surveying
- *Subpart I.7, Geothermics*
- Chapter 17, Geothermics: Heat and Temperature in the Earth
- *Subpart I.8, Subsurface Geophysics*
- Chapter 18, Well Logging and Other Subsurface Geophysics

Part II, Examples of Applications
- Chapter 19, Which Geophysical Methods to Use?
- Chapter 20, Global Tectonics
- Chapter 21, It the Kenya Rift a New Plate Margin? A Regional Geophysical Study
- Chapter 22, Hydrocarbon Exploration
- Chapter 23, Exploration for Metalliferous Ores
- Chapter 24, Volcanoes
- Chapter 25, The Chicxulub Structure and the K/T Mass Extinction
- Chapter 26, Hydrogeology and Contaminated Land
- Chapter 27, Location of Cavities and Voids
- Chapter 28, Archaeological Site Surveying

Clearly, this text covers a lot of ground, but does so very well at an undergraduate level. Successful exposition of basic physical principles and the interrelated nature of geological and geophysical investigation are what make this book such an enjoyable and compelling read. I especially enjoyed aspects of Part II, largely due to the breadth of applications covered. I found chapters 26, 27, and 28, although short, particularly interesting (a reflection of cavities and voids in my own background). Some will surely quibble that this or that specific topic is too briefly discussed, but I felt very comfortable with the relatively uniform level of coverage. In many cases, the authors' use of inset boxes to highlight and expand upon select topics provides the additional, more in-depth information that some readers will desire.

The hardback edition lists for US$110, reasonable for a book of this size and quality. However, where Cambridge University Press really shines is in offering a paperback edition for only US$42.95: a very attractive price for an undergraduate text. If this book had been around when I was an undergraduate, it might have encouraged me to follow a different path, and saved me a lot of subsequent grief wading through bogs, thrashing through bush, and clinging to cliff-loving vegetation (but I digress). I anticipate that *Looking into the Earth* will become a standard textbook for years to come, stimulating the quantitative sides of impressionable minds.