Introduction

John Wakabayashi

Department of Earth and Environmental Sciences, California State University, Fresno, California 93740, USA

Yildirim Dilek

Department of Geology and Environmental Earth Science, Miami University, Oxford, Ohio 45056, USA

This volume honors one of the most accomplished geologists of his generation, Eldridge Moores, beginning with a brief summary of his achievements and personal dedications and memories from people who knew him (“Eldridge M. Moores, His Accomplishments, Service, and Legacy”), followed by 12 chapters of original scientific contributions.

Eldridge’s last published paper (Moores et al., Chapter 1) leads off the volume’s scientific contributions. This paper presents geochemical data from the Indian Ocean data and tomography from the Indian Ocean and flanking regions. These data are used to support a proposal that the arc-like geochemistry of southeast Indian Ocean lavas, erupted at a mid-ocean ridge, was a consequence of an earlier stage of subduction that modified the overlying mantle that would later partially melt to form mid-ocean ridge magma. This paper represents an example of the concept of Historical Contingency (Moores et al., 2000), which suggested that earlier subduction history may result in supra-subduction zone geochemical signatures for some magmas formed in non-subduction environments. Co-authors Simmons and Basu have each contributed dedications to Eldridge in the dedication section of this volume. Note that since the final revision of the paper in this volume, at least one paper has been published that strongly supports the Historical Contingency concept in young (7 Ma) rocks in a well-constrained tectonic setting. This is van Hinsbergen et al. (2020), which shows that the arc-like geochemistry of lavas erupted long after subduction termination in New Guinea was a result of partial melting of mantle affected by the earlier subduction.

Das and Basu (Chapter 2) appropriately follows Chapter 1 in the sense that they use their data to propose a Historical Contingency scenario in which a Neo Tethyan ophiolite in the Himalaya (Indus ophiolite, referred to as the Nidar ophiolite in some earlier works) was formed in a mid-ocean ridge environment from mantle modified by earlier subduction. The paper examines high-pressure and ultrahigh-pressure phases in peridotite associated with ophiolite. The progressive growth of these phases tracks the solid-state upwelling of this mantle rock from depth of the mantle transition zone (~410–660 km), as well as changes in oxygen fugacity and presence of CO₂. These data are used to propose a new model for partial melting beneath a mid-ocean ridge and generation of mid-ocean ridge basalt (MORB). In addition to providing a dedication, Basu is also one of the co-authors of the Geological Society of America (GSA) memorial to Eldridge (Dilek et al., 2020).

Rassios and Grieco (Chapter 3) take up the theme of societal significance of geology in answering the question posed in the title of the paper, that the documentation of geoheritage sites is cutting-edge scholarship, rather than a simple descriptive exercise. The two sites in Greece have different societal significance. At one, the Meteora World Heritage site, the geologic history directly impacted the development of the Byzantine monastic community. The other, the Aliakmon Legacy Project, highlights geologic relationships associated with the Vourinos Ophiolite that were crucial outcrops that helped launch discoveries of the Plate Tectonic revolution, particularly the connection between ophiolites and oceanic crust (e.g., Moores and Vine, 1971), and subsequent research. These outcrops became a focal point of tectonic studies as a result of the detailed research of Eldridge Moores during his postdoctoral studies (1963–1966) that was published as Moores (1969). Rassios, who was a Ph.D. student of Eldridge, also provided a dedication to Eldridge in this volume as well as a separate contribution submitted to a collection...

Rassios et al. (Chapter 4) present a review of decades of research on high-temperature deformation fabrics formed in the vicinity of the “petrological Moho” or crust-mantle boundary preserved in the Vourinos Ophiolite and present new interpretations connected to the nature, distribution and origin of these fabrics. The deformational history includes symmagmatic folding and rotation of the petrological Moho. They explain the complex deformation of the oceanic mantle and lower crust as being associated with nascent oceanic fracture zone formation. Much of this work is from outcrops associated with the Aliakmon Legacy site of Chapter 3, and it is research that built on the pioneering work of Eldridge Moores on the Vourinos Ophiolite. In addition to Rassios, Dilek was also a Moores Ph.D. student, and Ghikas was his master’s student. Dilek is also the lead author of the GSA memorial to Eldridge Moores (Dilek et al., 2020).

Francis et al. (Chapter 5) present detailed geologic mapping, seismic refraction and oxygen isotope data, from the area mapped by Moores et al. (1968). In addition to refining knowledge of fault geometry, the data and observations show a mélangé zone, as well as defining a zone of silicified carbonates formed by hydrothermal fluids apparently directed along detachment faults. This data is used to develop a structural model of coalescing, stacked detachment faults rooted in ductily deformed rocks that accommodate the regional extension. Francis has provided a dedication to Eldridge in the dedication section that further details the connection between Moores et al. (1968) and the research presented in Chapter 5.

Zhang et al. (Chapter 6) present 2-dimensional numerical models of west-dipping subduction and subsequent collision (subduction termination) in the North American Cordillera. These models show the sensitivity of post-collisional slab breakoff to various parameters and make predictions for surface topography, including a 2-km increase in elevation west of the suture and a foreland region extending >1000 km east of the suture with ~4 km of subsidence relative to adjacent regions. This work addresses an enduring point of major controversy in North American Cordilleran tectonics, which is whether the orogenic belt evolved with an episode or episodes of west-dipping subduction in addition to east-dipping subduction (e.g., Moores, 1970), or if the Cordillera assembled entirely as a consequence of prolonged east-dipping subduction (e.g., Hamilton, 1969).

Díez Fernández et al. (Chapter 7) present detailed structural geologic relationships from Variscan rocks of southwest Iberia. These relationships show the offset of a former subduction suture marked by serpentinitized peridotite by a later thrust. The restoration of the considerable post-suture deformation and faulting allows determination of the original subduction zone polarity. The connection between ultramafic rocks and subduction suturets in orogenic belts was initially made in pioneering papers of the plate tectonic revolution by Moores (1970) and Dewey and Bird (1970). Whereas orogenic belt research has used these foundational concepts, it is difficult to distinguish primary subduction-related contacts from later ones in many orogenic belts. Chapter 7 presents a good example of the value of detailed field work that facilitates the identification and analysis of primary orogenic structures.

Boniface and Tsujimori (Chapter 8) present a review of lithologic, geochemical, geochronologic, and metamorphic petrologic data of rocks, including eclogites, as well as new U-Pb zircon ages from the Uberdian-Usagaran orogenic belt of Tanzania. The study documents a protracted superimposed orogenic history including eclogite (subduction zone) metamorphism at ca. 2000, 1920, 1860–1890, and 500–590 Ma. The older rocks record some of the oldest eclogite facies metamorphism found in the world, and the tectonic model for evolution of the orogenic belt proposes the existence of multiple subduction zones of different polarities that were active from ca. 2100 to 1860 Ma with subsequent rifting of the orogenic belt from 1400 to 740 Ma and consumption of these younger basins by subduction from 590 to 500 Ma. This paper, and subsequent chapters 9, 11, and 12 in the present volume, involve another important marker of paleosubduction zones, in addition to ophiolites, the primary orogenic “marker” of Moores (1970), which is subduction zone metamorphism, the initial connection for which was also a part of the plate tectonic revolution (Ernst, 1970). Ernst, a co-author of Chapter 9, has also contributed a dedication to Eldridge Moores in this volume.

Fedkin et al. (Chapter 9) present new pressure-temperature estimates and whole-rock geochemical data from ultrahigh-pressure eclogites of the Maksyutov subduction complex of the south Ural Mountains of Russia. Both conventional Fe-Mg exchange thermometry and thermodynamic phase equilibria (pseudosection) modeling record P-T conditions that reflect higher temperatures but lower pressures than those associated with the growth of ultrahigh pressure phases (such as coesite and diamond) in these rocks. This suggests warming during the deep exhumation path of these rocks.

Ogawa and Mori (Chapter 10) present detailed structural geologic data from Miocene-Pliocene strata of the Miura accretionary complex, exposed along the Pacific coastline of Japan south of Tokyo. These structures, which include imbricate faults, duplexes, and mélanges, are different for thrusting associated with accretion compared to those associated with gravitational sliding of units into the trench. The former is distinguished from the latter on the basis of association with features consistent with movement in a semi-lithified state, such as diapiric and sedimentary dike and sill structures, as well as more random vergence of folds. Mélanges are another geologic feature that has come to be associated with paleosubduction zones, following work of Hsü (1968, 1971), and interpretation of the origin of mélanges is an important part of Chapter 12. Eldridge Moores maintained research interest in subduction complex rocks and associated formational processes, including mélangé development, from his early years at UC Davis. This is reflected by the
fact that his first Ph.D. student, Loren Raymond, was one of a cohort of Eldridge Ph.D. students who conducted research on the Franciscan Complex of coastal California. This group of students and Eldridge published the first synthesis of Franciscan Complex geology in the wake of the Plate Tectonic revolution (Berkland et al., 1972). Ogawa and Raymond have each contributed dedications to Eldridge in the dedication section.

Apen et al. (Chapter 11) present detrital zircon data from metasediments from the Franciscan Complex. They integrate the new data and published detrital zircon data on Franciscan metasediments to tackle the difficult problem of regional-scale correlation of units within a subduction complex. They propose a regional correlation of a pair of tectonically stacked units over distances of >50 km, restoring post-subduction strike-slip faulting. The authors also suggest differential exhumation of one potentially correlative unit that records prehnite-pumpellyite facies metamorphism in the San Francisco Bay region but lawsonite blueschist facies metamorphism in the southern Diablo Range. Wakabayashi, the second author, was the last of Moores’ Ph.D. students to study the Franciscan Complex as a dissertation topic. He has contributed a dedication to Eldridge in this volume, a separate one in the thread on the UC Davis Website, https://geology.ucdavis.edu/people/inmemoriam/moores/memories, and he is a co-author of the GSA memorial to Eldridge Moores (Dilek et al., 2020).

Wakabayashi (Chapter 12) presents detailed field and petrographic data and a review of previous data from the Franciscan Complex. He defines two types of subduction faults preserved in the subduction complex, those associated with accretion, and those associated with non-accretion or subduction erosion. He interprets the field and petrographic data to suggest that most subduction and slip is accommodated in narrow fault zones of 20 m thickness or less and that fault slip associated with exhumation of Franciscan rocks was similarly localized. He presents three different methods of estimating subduction fault slip associated with accretion during the extended (ca. 150 Ma) history of Franciscan subduction and concludes that accretionary subduction slip was much less than the non-accretionary subduction slip during the same period.

ACKNOWLEDGMENTS

We thank John M. Bartley, Timothy Byrne, Fernando Corfu, Kennet Flores, Chiara Frassi, Stephen T. Johnston, Petros Koutsovitis, Juhn G. Liou, J. Brendan Murphy, Euan G. Nisbet, Kei Ogata, Manuel Francisco Pereira, Loren A. Raymond, Konstantinos Soukis, Christopher Spencer, Wanda Taylor, Tatsuki Tsujimori, Agni Vamvaka, Haibo Zou, and the anonymous reviewers who reviewed chapters for this volume.

REFERENCES CITED


Manuscript accepted by the society 2 April 2021

Printed in the USA