International Geology Review, 2015
Vol. 57, Nos. 5–8, v–ix, http://dx.doi.org/10.1080/00206814.2015.1026415

INTRODUCTION

Convergent plate margin processes and their rock record

Convergent plate margins are key features of our dynamic planet, and the processes taking place along such margins have had a correspondingly large impact on society and the geologic record. As with many aspects of the geosciences, new insights into the workings of present-day convergent margins facilitate analysis of the rock record of such processes, and the rock record helps us understand active processes at depths below the present level of observation, brought to the surface by erosion and exhumation.

The 23 papers in this special issue present research on a variety of localities around the world (Figure 1) and span a wide range of geoscience research disciplines, including structural and sedimentary geology, metamorphic petrology, igneous petrology and geochemistry, geochronology, and seismology. The sparks for this volume were four closely related, internationally themed technical sessions held at the Geological Society of America Cordilleran Section Annual Meeting in Fresno, California, in May 2013. Papers related to presentations given in those sessions form the nucleus of the special issue, but this issue includes additional contributions not associated with those technical sessions.

Another purpose of this special issue is to honour W. Gary Ernst (Figure 2) for his many years of service as Editor of *International Geology Review*, as well as for his seminal contributions to our understanding of convergent plate margin processes and their rock record. Under Gary's leadership from 1995 to 2013, *International Geology Review* was transformed from an obscure publication of mostly translations of Soviet geoscience into a premier and truly international geoscience journal.

Organization of a volume such as this is not an easy matter, because all of the papers are process-oriented in some way in addition to being connected to localities. In this volume we have chosen to group some papers by region and others by subject. We have nine papers that highlight aspects of California–Arizona geology (or Franciscan Complex and related rocks). Five of the Franciscan Complex papers focus on mélanges, so it would have been equally appropriate to group them with the five papers we have grouped within the mélange theme. The five papers representing the mélange theme include one on global localities, one from coastal Chile, two on parts of the Alpine orogen, and one on part of the Variscan orogen. Our other subject-oriented group comprises two papers on mantle fabrics. There are two more broad regional groupings of three papers in the greater Central America–Caribbean area and five papers covering Eurasia and the West Pacific. We summarize these papers below.

Mélanges

Using examples from different orogenic belts around the world, Wakita (2015) proposes a new category of mélange, the ocean plate stratigraphy (OPS) mélange, as an important indicator of accretionary complex processes. Such mélanges developed by disruption (tectonic or sedimentary processes or both) of ocean floor assemblages made of oceanic volcanic rocks, progressively overlain by pelagic sedimentary rocks and clastic sedimentary (trench-fill) rocks.

Festa *et al.* (2015) describe unmetamorphosed olistostromes in the exhumed Ligurian accretionary prism of the Northern Apennines of Italy. They relate these units to the formation of mass transport complexes (large submarine landslides) that are common in modern trench slope/accretionary wedge front environments.

Alonso *et al.* (2015) show that unmetamorphosed mélanges from the Variscan orogenic belt in Spain occur in distinct geologic settings, including mélange carpets underlying thrust systems and olistostromes. The former are interpreted to have formed during extension of semilithified units during gravitational collapse of advancing submarine nappes, whereas the latter formed by debris flows from subaerial nappe fronts or from carbonate platforms on the lower plate.

Balestro *et al.* (2015) present observations on three types of eclogite facies mélange with different lithologies and block-matrix relationships from the Western Alps. All three types of mélange show block-in-matrix development owing to tectonic strain, superimposed in some cases on horizons that experienced earlier sedimentary introduction of exotic blocks or clasts.

Kato and Godoy (2015) describe mélanges from the central Chilean coast and show the overprinting of accretionary complex fabrics by high-angle transpressional fabrics that accommodated significant exhumation. These rocks include *in situ* blueschist facies rocks with varying degrees of greenschist facies overprint, as well as exotic blocks with blueschist, eclogite, and amphibolite facies assemblages.

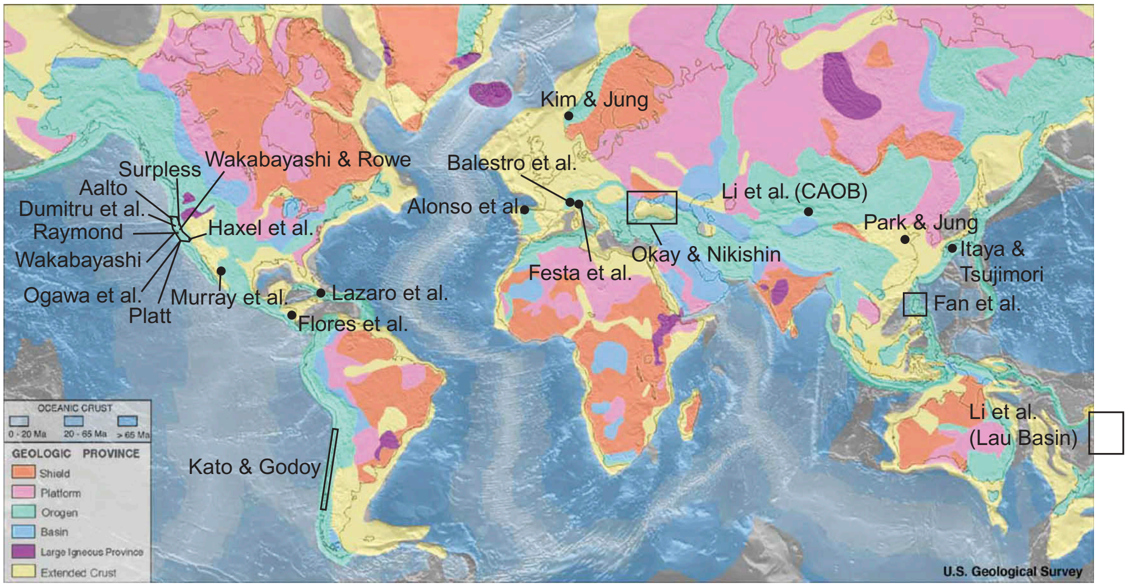

Figure 1. Map showing the locations of the studies presented in this volume. The paper by Wakita covers multiple accretionary complexes of the world, so it does not have a specific location shown on the map. Basemap shows geologic provinces of the world and was generated by USGS.

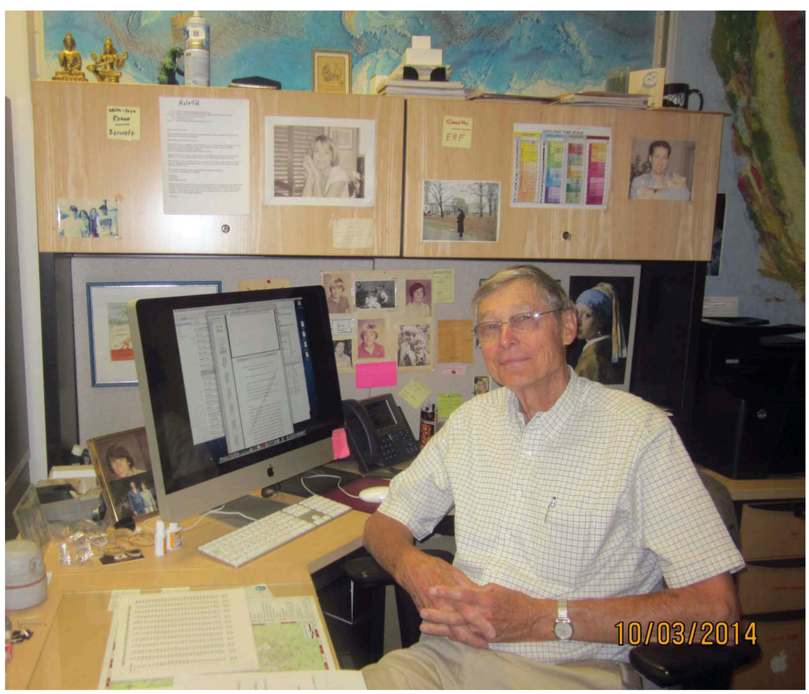

Figure 2. Photograph of W. Gary Ernst in his office at Stanford University. Photograph by J.G. Liou.

Mantle fabrics

Park and Jung (2015) present data on microfabrics of mantle xenoliths from eastern China and relate these fabrics to seismic anisotropy of this region. They conclude that the seismic anisotropy formed as a result of superposition of deformation events recorded in the olivine linear preferred orientations of the xenolith samples, the first of which formed by lateral shear during or shortly following Mesozoic Sino-Korean/South China continental collision, and the second of which formed by extension related to the westward subduction of the Pacific plate.

Kim and Jung (2015) describe microstructures in olivine and chlorite from chlorite peridotites from the Western Gneiss Region of Norway and calculate the seismic anisotropy of olivine and chlorite. They conclude that the strong linear preferred orientation in chlorite-bearing peridotites may be a source of seismic anisotropy in the mantle wedge above subduction zones as well as within subducting slabs.

California and Arizona: Franciscan Complex and related units

Wakabayashi (2015) presents new field and petrographic data and reviews published work on the Franciscan subduction complex of coastal California, spanning a range of scales from hundreds of kilometres to thin sections. These observations are interpreted in the context of convergent plate margin processes, including subduction and accretion history, localization of deformation, mélange evolution, and exhumation of high-pressure metamorphic rocks.

Surpless (2015) presents geochemical data from Cretaceous fine-grained clastic rocks of the Great Valley Group forearc basin strata of central California and uses these data to evaluate provenance. She shows that geochemistry of clastic rocks records mafic–ultramafic sources missed by detrital zircon provenance analysis, that the provenance record of the northern (Sacramento basin) part of the forearc basin differs from that of the southern (San Joaquin basin) part, and that sediment sources inboard (east of the Sierran–Klamath) magmatic arc are not required to explain the geochemistry or detrital zircon record of the basinal strata.

Dumitru *et al.* (2015) present around 2400 U–Pb detrital zircon ages from 26 sandstone samples from a transect across the Franciscan Complex of the northern California Coast Ranges. These ages significantly increase available data on the sources of Franciscan clastic sediment, and accretionary timing, as well as showing that many of the Franciscan megafossil localities have been reworked.

Raymond (2015) presents field data on Franciscan Complex exposures of the northeastern Diablo Range and reviews work on correlative units throughout the complex, pointing out many inconsistencies with application of terrane nomenclature, especially for the Yolla Bolly and Central terranes. He concludes that local lithologic and/or structurally specific unit names are more useful in characterizing subduction complex geology than terrane names.

Aalto (2014)[1] summarizes the results of over two decades of his detailed field work on Franciscan Complex mélanges of the northernmost California Coast Ranges. He classifies the various mélanges into four different types following the scheme of Cowan (1985): broken formation derived from interbedded sandstone and mudstone (type I) or from interbedded green tuff, radiolarian chert, minor sandstone, and mudstone (type II), disrupted by layer-parallel coaxial extension, type III olistostromes made up of chaotic mixtures of varied lithologies in a little-deformed to scaly pelitic matrix, and type IV tectonic mélanges comprising strongly foliated pelitic and/or serpentinite matrix with a variety of blocks, formed along regional fault zones.

Ogawa *et al.* (2015) and Platt (2015) present contrasting interpretations of detailed field observations from the classic Franciscan Complex mélange exposures of San Simeon, along the central California coast. Platt interprets the block-in-matrix character and lithologic mixing of the mélanges to have originated from submarine sliding down the inner trench slope, followed by variable overprinting by extensional fabrics developed during the late-stage deformation within the subduction complex. Ogawa suggests that the mélanges formed in a subduction channel and then diapirically intruded trench-fill sediments represented by the Cambria slab and related rocks.

Wakabayashi and Rowe (2015) present observations from what they interpret as an exhumed subduction megathrust separating two Franciscan Complex nappes at the El Cerrito Quarry locality in the San Francisco Bay area. They conclude that significant displacement was localized along the upper contact of a mélange, whereas the mélange was formed by sedimentary processes rather than megathrust slip.

Haxel *et al.* (2015) describe peridotite bodies in southwestern Arizona associated with the most inland exposure of the latest Cretaceous to early Palaeogene Orocopia schist, regarded by most as an inboard equivalent of part of the Franciscan subduction complex. They suggest that these ultramafic bodies were derived from the mantle wedge overlying the subduction zone.

Central America and Caribbean region

Murray *et al.* (2015) present field and geochronologic data from early Oligocene to early Miocene volcanic rocks in the Cerocahui basin of the northern Sierra Madre Occidental silicic large igneous province of northwest Mexico. They show that the timing of extensional deformation and magmatism in the basin and region generally coincided with rollback of the Farallon slab.

Lázaro *et al.* (2015) present $^{40}Ar/^{39}Ar$ hornblende cooling ages from the metamorphic sole beneath the Moa-Baracoa ophiolite of eastern Cuba, and geochemical data from the ophiolite and metamorphic sole. They suggest that the metamorphic sole protoliths and ophiolite formed in a similar supra-subduction zone environment and that the subduction initiation event that formed the metamorphic sole was triggered by the main plume pulse of the Columbian–Caribbean Oceanic Plateau.

Flores *et al.* (2015) present metamorphic and geochronological data from blocks from the Siuna Serpentinite Mélange of northeastern Nicaragua. Blocks from the southern and central parts of the mélange have volcanic and pelagic protoliths which record lower-grade conditions of prehnite-pumpellyite/greenschist and possible blueschist facies, whereas blocks from the northern part of the mélange are exclusively metamafic and record higher-grade conditions and a metamorphic evolution from blueschist to eclogite to amphibolite facies. A 139 Ma phengite $^{40}Ar/^{39}Ar$ date from a block is suggested to record cooling during exhumation along the southern edge of the continental Chortis Block.

Asia and Western Pacific region

Li *et al.* (2015a) review the spatial variations in published geochemical data from basaltic lavas of the Lau Basin of the southwest Pacific Ocean, evaluating the influence of the subducted Louisville seamount chain on magmagenesis. They conclude that significant variability of basalt geochemistry resulted from contributions from Louisville seamount materials rather than reflecting variations in mantle fertility, or Pacific *versus* Indian Ocean mantle.

Fan *et al.* (2015) present tomographic data from the vicinity of the Manila Trench in the Philippines of the western Pacific Ocean to evaluate the geometry of the subducted South China Sea slab. They show significant along-strike variation in the dip of the slab and a possible slab tear between 17° and 17.5° N that appears to coincide with a fossil ridge axis, as well as a gap in upper plate volcanism

Itaya and Tsujimori (2015) present white mica K–Ar dates from eclogitic rocks of the Sanbagawa belt of Southwest Japan. They suggest that their data indicate the influence of deformation and related recrystallization on Ar closure temperature, as well as on incorporation (or retention) of excess Ar derived from subducted sediments.

Li *et al.* (2015b) present U–Pb zircon ages and geochemistry of ophiolitic and associated rocks from the North Tianshan region of the Central Asian Orogenic Belt. The rocks show an island arc geochemical affinity, and the youngest ages of ca. 300 Ma indicate that subduction and island arc development in this part of the long-lived orogenic belt persisted until that time.

Okay and Nikishin (2015) review geological evidence bearing on the tectonic evolution of the southern margin of Laurasia of the Black Sea region, a complex orogenic region that received comparatively little attention until relatively recently. The region is interpreted to have formed as a result of closure of multiple ocean basins by subduction that led to development of multiple magmatic arcs, accretionary complexes, and ophiolite belts.

Conclusions

Each paper in this volume contributes to understanding convergent plate margin processes and their rock record. Having these papers together makes them an even better resource for geoscientists. We expect this volume to benefit researchers and students for years to come. As such, we hope the volume will serve as a worthy tribute to the research of W. Gary Ernst and his many years of service as Editor-in-Chief of *International Geology Review.*

Acknowledgements

We thank Editor-in-Chief Robert Stern for inviting this special issue and for his careful and timely editorial handling of the papers. We also thank the reviewers of the papers; their time and effort greatly improved the quality of the papers.

Note

1. Although intended for publication in this special issue, this article was earlier published in *International Geology Review*, v. 56, p. 555–570.

John Wakabayashi
Department of Earth and Environmental Sciences, California State University, Fresno, CA 93740-8039, USA

Tatsuki Tsujimori
Pheasant Memorial Laboratory, Institute for Study of the Earth's Interior, Okayama University, Tottori-ken, Japan

Yujiro Ogawa
Professor Emeritus, University of Tsukuba, Yokodai, Japan

John Shervais
Department of Geology, Utah State University, Logan, Utah 84322-4505, USA

References

Aalto, K.R., 2014, Examples of Franciscan Complex mélanges in the northernmost California Coast Ranges, a retrospective: International Geology Review, v. 56, p. 555–570. doi:10.1080/00206814.2013.879841.

Alonso, J.L., Marcos, A., Villa, E., Súarez, A., Merino-Tomé, O. A., and Fernández, L.P., 2015, Mélanges and other types of block-in-matrix formations in the Cantabrian Zone (Variscan Orogen, northwest Spain): origin and significance: International Geology Review, v. 57, p. 563–580. doi:10.1080/00206814.2014.950608.

Balestro, G., Festa, A., and Tartarotti, P., 2015, Tectonic significance of different block-in-matrix structures in exhumed convergent plate margins: examples from oceanic and continental HP rocks in Inner Western Alps (northwest Italy): International Geology Review, v. 57, p. 581–605. doi:10.1080/00206814.2014.943307.

Cowan, D.S., 1985, Structural styles in Mesozoic and Cenozoic mélanges in the western Cordillera of North America:

Geological Society of America Bulletin, v. 96, p. 451–462. doi:10.1130/0016-7606(1985)96<451:SSIMAC>2.0.CO;2.

Dumitru, T.A., Ernst, W.G., Hourigan, J.K., and McLaughlin, R. J., 2015, Detrital zircon U-Pb reconnaissance of the Franciscan subduction complex in northwestern California: International Geology Review, v. 57, p. 767–800. doi:10.1080/00206814.2015.1008060.

Fan, J., Wu, S., and Spence, G., 2015, Tomographic evidence for a slab tear induced by fossil ridge subduction at Manila Trench, South China Sea: International Geology Review, v. 57, p. 998–1013. doi:10.1080/00206814.2014.929054.

Festa, A., Ogata, K., Pini, G.A., Dilek, Y., and Codegone, G., 2015, Late Oligocene–early Miocene olistostromes (sedimentary mélanges) as tectono-stratigraphic constraints to the geodynamic evolution of the exhumed Ligurian accretionary complex (Northern Apennines, NW Italy): International Geology Review, v. 57, p. 540–562. doi:10.1080/00206814.2014.931260.

Flores, K., Skora, S., Martin, C., Harlow, G.E., Rodriguez, D., and Baumgartner, P.O., 2015, Metamorphic history of riebeckite- and aegirine-augite-bearing high-pressure–low-temperature blocks within the Siuna Serpentinite Mélange, northeastern Nicaragua: International Geology Review, v. 57, p. 943–977. doi:10.1080/00206814.2015.1027747.

Haxel, G.B., Jacobson, C.E., and Wittke, J.H., 2015, Mantle peridotite in a newly discovered far-inland subduction complex, southwest Arizona: initial report: International Geology Review, v. 57, p. 871–892. doi:10.1080/00206814.2014.928916.

Itaya, T., and Tsujimori, T., 2015, White mica K–Ar geochronology of the Sanbagawa eclogites from Southwest Japan: implications for deformation-controlled K–Ar closure temperature: International Geology Review, v. 57, p. 1014–1022. doi:10.1080/00206814.2014.973915.

Kato, T.T., and Godoy, E., 2015, Middle to late Triassic mélange exhumation along a pre-Andean transpressional fault system: coastal Chile (26°–42° S): International Geology Review, v. 57, p. 606–628. doi:10.1080/00206814.2014.1002119.

Kim, D., and Jung, H., 2015, Deformation microstructures of olivine and chlorite in chlorite peridotites from Almklovdalen in the Western Gneiss Region, southwest Norway, and implications for seismic anisotropy: International Geology Review, v. 57, p. 650–668. doi:10.1080/00206814.2014.936054.

Lázaro, C., García-Casco, A., Blanco-Quintero, I.F., Rojas-Agramonte, Y., Corsini, M., and Proenza, J.A., 2015, Did the Turonian–Coniacian plume pulse trigger subduction initiation in the Northern Caribbean? Constraints from $^{40}Ar/^{39}Ar$ dating of the Moa-Baracoa metamorphic sole (eastern Cuba): International Geology Review, v. 57, p. 919–942. doi:10.1080/00206814.2014.924037.

Li, C., Xiao, W., Han, C., Zhou, K., Zhang, J., and Zhang, Z., 2015b, Late Devonian–early Permian accretionary orogenesis along the North Tianshan in the southern Central Asian Orogenic Belt: International Geology Review, v. 57, p. 1023–1050. doi:10.1080/00206814.2014.913268.

Li, Z.-G., Chu, F.-Y., Dong, Y.-H., Liu, J.-Q., and Chen, L., 2015a, Geochemical constraints on the contribution of Louisville seamount materials to magmagenesis in the Lau back-arc basin, SW Pacific: International Geology Review, v. 57, p. 978–997. doi:10.1080/00206814.2014.922903.

Murray, B.P., Busby, C.J., and Verde Ramírez, M.D.L.A., 2015, Extension and magmatism in the Cerocahui basin, northern Sierra Madre Occidental, western Chihuahua, Mexico: International Geology Review, v. 57, p. 893–918. doi:10.1080/00206814.2014.941022.

Ogawa, Y., Mori, R., Tsunogae, T., Dilek, Y., and Harris, R., 2015, New interpretation of Franciscan mélange at San Simeon coast, California: tectonic intrusion into an accretionary prism: International Geology Review, v. 57, p. 824–842. doi:10.1080/00206814.2014.968813.

Okay, A.I., and Nikishin, A.M., 2015, Tectonic evolution of the southern margin of Laurasia in the Black Sea region: International Geology Review, v. 57, p. 1051–1076. doi:10.1080/00206814.2015.1010609.

Park, Y., and Jung, H., 2015, Deformation microstructures of olivine and pyroxene in mantle xenoliths in Shanwang, eastern China, near the convergent plate margin, and implications for seismic anisotropy: International Geology Review, v. 57, p. 629–649. doi:10.1080/00206814.2014.928240.

Platt, J.P., 2015, Origin of Franciscan blueschist-bearing mélange at San Simeon, central California coast: International Geology Review, v. 57, p. 843–853. doi:10.1080/00206814.2014.902756.

Raymond, L.A., 2015, Designating tectonostratigraphic terranes *versus* mapping rock units in subduction complexes: perspectives from the Franciscan Complex of California, USA: International Geology Review, v. 57, p. 801–823. doi:10.1080/00206814.2014.911124.

Surpless, K.D., 2015, Geochemistry of the Great Valley Group: an integrated provenance record: International Geology Review, v. 57, p. 747–766. doi:10.1080/00206814.2014.923347.

Wakabayashi, J., 2015, Anatomy of a subduction complex: architecture of the Franciscan Complex, California, at multiple length and time scales: International Geology Review, v. 57, p. 669–746. doi:10.1080/00206814.2014.998728.

Wakabayashi, J., and Rowe, C.D., 2015, Whither the megathrust? Localization of large-scale subduction slip along the contact of a mélange: International Geology Review, v. 57, p. 854–870. doi:10.1080/00206814.2015.1020453.

Wakita, K., 2015, OPS mélange: a new term for mélanges of convergent margins of the world: International Geology Review, v. 57, p. 529–539. doi:10.1080/00206814.2014.949312.