Pergamon

Journal of Structural Geology, Vol. 16, No. 8, pp. 1187 to 1189, 1994
Elsevier Science Ltd
Printed in Great Britain

BOOK REVIEWS

Overview of the Earth

Rogers, J. J. W. 1993. *A History of the Earth*. Cambridge University Press, Cambridge, England. 312 pp. Price: hardback £50.00; $89.95; paperback £22.95; $39.95.

Stop! Read no further! Get a pencil and paper and write down what *you* would include in the contents list if you were to write a book entitled *A History of the Earth*. Done that? OK, you may now read on.

If you are like me, you will have in front of you a seemingly endless list of possible topics which wander haphazardly from space and planetary accretion, through changes in plate tectonic and magmatic scenarios from the Archean to the present time, into missing links and global climate changes. You will also have a separate list where you have jotted down all the topics you cannot quite find a home for; *K–T* boundary, eustacy, geomorphology, sedimentary processes, mineralization. Need I go on?

It turns out to be a non-trivial question, and John Rogers is to be congratulated on his imaginative answer to it. The basic framework for any book that is "a broad introduction to this vast subject for all interested in the study of the Earth" has to be time, and that framework should focus the discussion of the evolution of both the lithosphere and the biosphere. This is indeed the pattern of this book, but, I must admit, not set out in the way that I was expecting.

The opening chapter, *Geologic Time*, lays the foundation naturally enough; discussing time from a radiometric, stratigraphic and biological point of view. Chapter 2, *Principal controls on Earth History*, homes in from the accretion and fractionation of the Earth, through the growth of oceanic and continental crust into sealevel changes. A discussion of how different the Earth was in Archean times precedes the chapter that will be of most interest to *JSG* readers, *Processes in a Rigid Lithosphere*. Most tectonic processes are touched on here, but the discussion is largely (and appropriately) held on a plate tectonic scale. There seems to be a clear preference for tectonic processes which help magmatism along.

From then onwards, the Proterozoic, Paleozoic (sic), Mesozoic and Cenozoic are discussed sequentially but from two contrasting standpoints; what was happening to life and the biosphere, and the tectonic evolution of the continents. The approach works well for the Palaeozoic, where life and lithosphere are dealt with in two chapters, but verges on the jumbled for the Earth's last 300 Ma. For me, the organization of the latter chapters is the weakest aspect of the book. I would have preferred to see the development of the biosphere through time completely separated from the discussion of lithospheric evolution through time. Perhaps it is just that I am comfortable with the more traditional approach.

Despite these reservations, the lucid style and the exceptionally clear illustrations carry the reader along, and the breadth of information that John Rogers has assembled in a book of just 300 pages is impressive. I particularly liked the light writing style that John adopts throughout. I offer you just two of many examples that made me chuckle; he basks in and alongside "the fine climate and many of the presumably happy organisms of the Cretaceous" before being rudely awoken by a bolide impact, and he astutely observes that "the combination of geology and scenery (perhaps also good restaurants) has invited intense geologic scrutiny of the Alps". I liked too his little asides, scattered throughout the text, that often encapsulate in just a couple of words some of the problems that arise through dodgy data or wobbly logic.

Inevitably when you review a book as broad as this, you find yourself assessing its accuracy by looking at the subjects you are familiar with. I would caution any British Caledonide specialist not to attempt this, because the reconstruction of our beloved region is hopelessly wrong. For example, I was tickled by the southeastward vergence of the Welsh Caledonian "major thrust belt" and the closure of the suture between Scotland and England in "Hercynian/Variscan/Arcadian times". But I do not believe such slips are symptomatic of poor standards generally; merely the sort of inaccuracy that our geologic cousins across the pond like to tease us with from time to time.

In my opinion the book does fall down fairly seriously in one of its stated aims. John hopes that the book "can provide an overview of the Earth for students who will then go directly into a study of a speciality within the earth sciences". It is much too complex in parts to do that. I struggled with Proterozoic biochemistry and Archean terranes, and if I had only a basic grounding in earth science many other aspects of the book would have intimated me, too. But if that is a fault, then it is one made by most who attempt to write to such a daunting brief. It does mean, however, that this book will be of more use to trained rather than training geologists.

Inevitably, there is a strong leaning towards the American way of doing things. We have learned to live with the Pennsylvanian, but in places the paucity of non-American references when subjects of global interest are discussed smacks a little of parochialism. But the good features of this book easily outweigh the less good ones. It is a good read, and I am glad I possess a copy. I know I shall return to it again and again for reference material with a refreshing 1990s approach to earth science. Mischieviously, I found myself wondering, since the book ends so abruptly, if there is to be a sequel. Just when you thought it was safe to go back into the Proterozoic.

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Global-scale wrenching

Xu Jiawei (editor) 1993. *The Tancheng-Lujiang wrench fault system*, John Wiley, Chichester, England. 279+xv pp. ISBN 0-471-9332-5. Price: hardback £100.

The Tancheng-Lujiang (or Tan-lu) fault zone (TLFZ) is a major NNE-trending strike-slip fault zone in eastern China. Its ~750 km left-lateral displacement probably developed during a single phase of early Cretaceous activity, with slip rate ~50 mm y^{-1} during ~115–100 Ma. It was discovered in the 1950s by Xu Jiawei. Xu is now Professor of Geology at Hefei University, which is near Lujiang within the TLFZ. He compiled the 19 papers in this book following a symposium which he organized in 1989.

Luijiang is near the Yangtze river, ~800 km south of Beijing and ~400 km west of Shanghai near the East China Sea coast. Early studies traced the TLFZ northward from Lujiang to the coast east of Beijing, ~300 km NNE of Tancheng. This ~650 km remains the best-documented. It crosses the suture of the Paleotethys ocean, which once separated the Sino-Korean (North China) and Yangtze (South China) plates. The >500 km offset of this suture and the neighbouring rocks was first reported by Ferdinand von Richtofen in 1898. It was explained by Xu in the early 1960s as an introduction of substantial left-lateral displacement on the TLFZ.

Because this first length of the TLFZ to be recognized crosses the Paleotethys suture, most of the literature regards it as having slipped during closure of this ocean and the associated continental collision during the "Indosinian" oregeny. Although several contributors to this book follow this hypothesis, others present contradictory evidence. This part of the Paleotethys ocean closed no later than Triassic time (~220–200 Ma). However, stratigraphic evidence (best presented in Chapter 7) demonstrates Early Cretaceous (~115–100 Ma) slip on the TLFZ. Several other chapters address the more likely possibility that the TLFZ took up motion between Eurasia and a plate within the Pacific basin. The NNE–NE structural trend of eastern China and neighbouring regions (Japan, Korea, and easternmost Russia) evidently resulted from slip on the TLFZ and other faults that are also subparallel to this ocean margin. It thus records part of the complex history of the Pacific basin, which is poorly understood during Mesozoic time.

Parts of this book contain new information that is significant for constraining the kinematics of eastern Asia and the Pacific basin. Other chapters provide detail on major structures and formations in the study region. It is rare that this sort of information about China is fully documented in English: one usually has to rely instead on summaries in review articles. Unfortunately, several other features made this book frustrating to review. First, many chapters are badly structured. Most lack any summary; several also lack any concluding section. Several chapters keep switching between descriptions of field localities, summaries of theory, or tectonic syntheses. The proliferation of schematic tectonic summary maps, some linking the TLFZ to closure of the Paleotethys, others linking it to the Pacific, is especially confusing. Second, in many ways the book is poorly presented. I lost count of the references that are either omitted from the bibliography or listed incorrectly, the localities discussed in the text that are not marked properly on any location map, and the important pieces of information (such as timings of faulting or amounts of displacement on major strike-slip faults) that are stated without supporting evidence. Third, seven of the chapters are by Xu or his departmental colleauges. Much of this material has been published before (e.g. Xu *et al.* 1986, 1987). There also seems to have been some blurring of Xu's roles as contributor and editor: in his introductory chapters, written as editor, he arbitrarily dismisses the results of others where they conflict with his own views. His strongest criticism concerns Chapters 7 and 18 (see below), which seem to me to present some of the most convincing and significant field evidence. An alternative order to the book would have been preferable, with field descriptions preceding syntheses, and with the resulting tectonic models constrained at least to be consistent with the available evidence.

The book has four sections. Part 1, the Introduction, has three chapters, all by Xu and his colleagues. These review the history of dicovery of the TLFZ, summarize key field observations including evidence for the ~750 km left-lateral offset, and discuss tectonic models. The nine chapters of the second section, "The Tancheng-Lujiang Fault Zone", present more detailed observations from the central part of the TLFZ that was discovered first. The five chapters of the third section, "The Tancheng-Lujiang Wrench Fault System", address other faults farther east and south, some which were not active at the same time as the TLFZ. The final section, "Related Regions", describes the Jurassic right-lateral Honam shear zone in South Korea and the Late Cretaceous left-lateral faulting in easternmost Russia, neither of which is tectonically equivalent to the TLFZ. The book is organized as a summary followed by a series of geographical groupings. This unfortunately means that the text keeps switching between time scales, adding to the already considerable potential for confusion.

Chapter 1, "Historical review and present setting" by Xu Jiawei, summarizes the history of investigations of the TLFZ, provides other background information, and reviews the rest of the book. Its discussion mixes models linking the TLFZ with the Pacific margin and the closure of the Paleotethys ocean. In Chapter 2, "Basic Characteristics and Tectonic Evolution of the TLFZ", Xu describes the central TLFZ between the Yangtze river and the coast east of Beijing. It includes some quite detailed maps and field descriptions, with considerable discussion of mylonites and other foliations in the surrounding deformed rock mass. Much of this material is repeated from Xu *et al.* (1986). Chapter 3, "Displacement on the Tancheng-Lujiang wrench fault system and its geodynamic setting in the northwestern circum-Pacific", by Xu Jiawei, Ma Guofeng, Tong Weixing, Zhu Guang & Lin Shoufa, is modified with some revision from the text of Xu *et al.* (1987). In contrast with Chapter 1, it only considers the hypothesis that the TLFZ took up margin-parallel slip between Eurasia and the Pacific basin. It also argues that the TLFZ and many other faults in and around eastern China are tectonically equivalent. However, a great deal of evidence, both in this volume and elsewhere, contradicts this second hypothesis.

Chapter 4, by Guo Zhengyi, is called "Structures, mechanisms and history of the middle segment (Yishu belt) of the TLFZ". It interprets the geology of the central TLFZ in roughly the same detail as was provided in Chapter 2. Its author believes that the TLFZ slipped leftward in Triassic and Jurassic time during closure of the Paleotethys ocean. Chapter 5, by Xu Xuesi, is "Late Precambrian Xuhuai-Jiaoliao sedimentary basin and horizontal displacement ot the TLFZ". The Xuhuai basin in central China, west of the TLFZ, and the Jiaoliao basin farther northeast in southern Manchuria and North Korea have very similar structure, and contain Late Precambrian sediments with very similar lithology. Both basins are situated just north of what is now the Paleotethys suture, suggesting that they developed near what was the southern margin of the Sino-Korean continent. They originally formed a single basin, which was later severed by left-lateral slip on the TLFZ. Restoring this offset constrains the displacement as ~550 km on this central part of the TLFZ. Chapter 6 is "Correlation between the Subei-Jiaonan and Dabie blocks and horizontal displacement of the TLFZ", by Sun Jinxiong, Chen Fengshang, Wang Guoping & Jin Yongnian. It describes Archean and early Proterozoic sequences near what used to be the northern margin of the Yangtze continent, which are now south of the Paleotethys suture (i.e. immediately south of the localities in Chapter 5). Although these rocks are more complex and difficult to interpret than those in the previous chapter, one marker is shown to also be offset ~500 km by slip on the TLFZ.

Chen Peiji's Chapter 7, "Timing of displacement along the TLFZ and the migration of late Mesozoic volcanism in eastern China" provides the best guide to the timing and displacement of the TLFZ. It compares the western Liaoning region (southwest Manchuria, ~300 km NE of Beijing) with eastern Heilongjiang (northeastern Manchuria, near the Russian frontier north of Vladivostok). Chen shows that these regions have very similar Late Jurassic and Early Cretaceous stratigraphy. The youngest documented rocks, now offset by ~750 km, belong to the Qingshan formation (121–119 Ma) west of the TLFZ and the correlated Jiande group (133–118 Ma) to the east. The oldest rocks that are not offset are Aptian/Albian (112–100 Ma). This northern part of the TLFZ thus slipped ~750 km during an interval that began no later than 118 Ma and ended no later than 100 Ma. This information, first published by Chen (1989), contradicts all the tectonic models presented in this book.

Chapter 8 is "Basement ductile shear belts along the TLFZ, Shandong province, eastern China" by Zhang Jiasheng. It looks at the plastic deformation fabrics in the Early Proterozoic rocks exposed east of the TLFZ in central China, which have already been considered in Chapter 6. These fabrics indicate left-lateral shearing, which has led some people to suggest that a fault zone equivalent to the TLFZ may have been active here in Precambrian time. Zhang shows instead that they have nothing to do with the TLFZ, which is entirely reasonable. Chapter 9, by Lu Peiji, is on "Blueschists of the high-pressure belts along the southern TLFZ". Blueschist metamorphism is documented within Archean rocks around the Paleotethys suture in some detail, and reports radiometric dates of ~230–200 Ma. These indicate metamorphism during the Triassic continental collision following closure of the Paleotethys ocean, consistent with other published timing evidence. This metamorphism of course has nothing to do with the TLFZ.

Chapter 10 is "Nature of the deformation at the southern of the TLFZ" by Tong Weixing. He argues that its ~750 km of left-lateral displacement dies out in a short distance south of the Yangtze river into zones of distributed deformation. This wild interpretation is at odds with other parts of the book (notably Chapters 13 and 15) that show major localized left-lateral displacement continuing farther south.

Chapter 11, "Late Mesozoic paleomagnetism in eastern China and the horizontal displacement of the TLFZ" by Zhu Ziwen, uses paleomagnetism to resolve the displacement on the TLFZ. Zhu shows that since Late Jurassic time sites west of the TLFZ (in stable Eurasia) have hardly moved: their paleolatitudes are $\sim 2 \pm 8°$ south of their present latitudes. Sites east of the TLFZ were instead $\sim 9 \pm 5°$ farther south. Although these results are of marginal statistical significance, given the error bounds, they are consistent with the view that the TLFZ has slipped leftward by ~750 km since Jurassic time.

Chapter 12, "Lithospheric structure and geophysical field, TLFZ, eastern China" by Wei Suyu and Teng Jiwen, is the only part of this book to deal with the active tectonics of the region adjoining the TLFZ. In some localities, strands of the TLFZ are now reactivated as right-lateral faults. Elsewhere, the TLFZ is no longer active and younger right-lateral faults slip instead. Some of these active faults are buried beneath the North China coastal plain, and were unexpected until the catastrophic Tangshan earthquake of 1976, which reputedly killed 500,000 people. This faulting is thus a subject of the utmost concern, and warrants better treatment than is found in this chapter.

Chapter 13 is "Horizontal displacement dynamics along the Yinhui-Gegongzhen fault, southern Anhui, China" by Liu Chang. It describes one of many left-lateral faults that appear to take up the TLFZ displacement south of the Yangtze river. The evidence presented indicates that this particular fault slipped ~9 km during Early Cretaceous time. Chapter 14 is "Structural and deformation characteristics of the southern segment of the Tianmushan-Baijishan major shear zone" by Zhu Guang. This shear zone is ~200 km inland of Shanghai, some ~300 km ESE of the TLFZ. There is the suggestion, without proper supporting evidence, of ~300 km displacement on this fault, but no evidence is presented for its timing. In Chapter 15, Liu Qing describes "Characteristics of the Xupu-Sangjiang fault zone and displacement of a paleolithofacies belt". This fault zone, 400 km inland of Hong Kong, offsets Early Paleozoic rocks by ~200–250 km. Allowing for 'drag' parallel to the fault, Liu estimates its displacement

as ~300 km. He states, without providing clear evidence, that this displacement developed during Jurassic time.

"Formation and evolution of the Ning-Wu pull-apart basin, lower Yangtze river" by Jiang Bo and Xu Jiawei comprises Chapter 16. This basin is ~100 km east of the TLFZ and ~200 km west of the locality described in Chapter 14. Although no quantitative dating evidence is presented, it is reported as associated with Late Jurassic and Early Cretaceous volcanic and sedimentary rocks. The adjoining left-lateral faults are ~30 km apart and overlap for ~80 km, suggesting a maximum of ~80 km displacement. The vagueness of the dating evidence makes it unclear whether this basin formed during ~115–100 Ma when the TLFZ was active or during some other deformation phase.

Chapter 17 is "Structural characteristics and deformation of the Changle-Nanao megashear zone along the southeast China coast" by Zhu Guang, Gao Denling, Lin Shoufa and Ma Guofeng. This shear zone runs a few kilometres inland of the Tawain Strait. Zhu *et al.* report evidence for Jurassic to Early Cretaceous and Late Cretaceous phases of left-lateral slip, but do not estimate its displacement. In Chapter 18 on "Honam, intra-arc transcurrent fault and Jurassic geodynamics in east Asia", S. C. Yanai, Y.-J. Jwa, S. Otoh, S. Yamakita, and B.-S. Park describe a NE-trending shear zone in South Korea. Yanai *et al.* demonstrate that it was active in late Jurassic time (~160–140 Ma) with *right-lateral* shear sense. From his introduction it is evident that Xu does not like this result: his models require all Mesozoic margin-parallel strike-slip faults in eastern Asia to be left-lateral, most mistakenly correlating it with the Changle-Nanao fault zone farther south (which is unequivocally left-lateral). Yanai *et al.* note that right-lateral shear would not result from the expected relative motion between Eurasia and any known adjoining plate within the Late Jurassic Pacific basin. They suggest that it was instead caused by microcontinent collision on the Neotethyan side of Eurasia. The Lhasa plate did indeed collide with Eurasia in Late Jurassic time.

Chapter 19, by V. P. Utkin, is on "Wrench faults of Sikhote-Alin and accretionary and destructive types of fault dislocation in the Asia-Pacific transition zone". A major Late Cretaceous NNE-trending left-lateral fault zone, the Sikhote-Alin has long been recognized inland of the Pacific margin between Vladivostok and the Sea of Okhotsk, but has no obvious link to the TLFZ. A less-well-documented fault 200 km farther west, which Utkin calls the Sungariisky fault and others in this book call the Yilan-Yitong fault, is in-line with the TLFZ and presumably tectonically equivalent to it. Utkin extrapolates a further continuation across the Sea of Okhotsk and eastern Siberia to the Arctic Ocean, labelled as the "East Kolymsky latent deep fault" and attributed to a missing reference. The preface, by Huang Jiqing (president of the Chinese Academy of Geosciences), tactfully describes this interpretation as bold.

The timing evidence is strong enough to preclude any relationship between left-lateral slip on the TLFZ and the closure of the Paleotethys ocean. The hypothesis, suggested by Xu *et al.* (1987) and repeated in Chapter 3, that slip on the TLFZ took up transcurrent motion between an oceanic plate (most likely Izanagi) and Eurasia during Early Cretaceous time (115–100 Ma) instead seems reasonable. As there is no evidence of subduction along the Eurasian margin at this time, the orientation of and displacement on the TLFZ thus constrain the Izanagi-Eurasia motion. This evidence may well indeed enable much stronger constraint than has so far been possible from the limited record of Pacific spreading centre magnetic anomalies and mantle plume tracks from this time. This is thus an unusual situation: one normally expects to use plate tectonics applied to ocean basins to predict the kinematics of deformation within neighbouring continents, not the other way round.

The wider hypothesis that the TLFZ is tectonically equivalent to most of the other margin-parallel strike-slip faults described in this book is however almost certainly wrong. This set includes the Changle-Nanao fault zone in southeast China, the Honam shear zone in South Korea, the Median Tectonic Line in Japan, and the "Korea–Taiwan Strait fault" that crosses the East China Sea shelf. However, the Honam shear zone is right-lateral (Chapter 18), and thus has no simple relationship with the other faults. Huang's preface points out that the "Korea–Taiwan Strait fault" is fiction: there is no evidence for it on the abundant seismic reflection profiles (from oil exploration) from the offshore region through which it allegedly passes. Chapter 17 shows that the Changle-Nanao fault zone slipped in Jurassic to Early Cretaceous time, then again in a separate Late Cretaceous slip phase. Two phases of left-lateral slip are also documented on the Median Tectonic Line: during latest Jurassic to earliest Cretaceous time, and from Late Cretaceous onward (e.g. Taira *et al.* 1989). These phases accompanied subduction, and presumably mean that the motion of the adjoining oceanic plate was oblique to the continental margin. They are thus not equivalent to the TLFZ, whose slip seems to occupy the interval between their two phases of activity that apparently marked a hiatus in subduction beneath Eurasia.

Allowing for the presence of en échelon strike-slip faults in some localities, the overall left-lateral displacement on the TLFZ and those faults to the north and south that are equivalent to it thus appears roughly uniform at ~750 km. During 115–100 Ma this fault zone linked the Sea of Okhotsk, which was then at the eastern limit of Eurasia, and the South China Sea. A southward continuation, which has yet to be discovered, presumably reached the southern (Neotethyan) margin of Eurasia. This is anticipated, given the substantial southern paleolatitude during 115–100 Ma of the spreading centre adjoining the Pacific plate at the southern boundary of the Izanagi plate (e.g. Engebretson *et al.* 1985). For a period of Early Cretaceous time lasting ~15 Ma, the TLFZ was thus one of the most important plate boundaries worldwide. Its ~500 km overall length, from the Sea of Okhotsk to southern Eurasia, made it far longer than any present-day active strike-slip fault zone. It was thus a major structure of global significance, and deserves proper recognition. Several contributors to this book draw analogies between the TLFZ and the modern San Andreas fault zone. However, the TLFZ was in a different league entirely: at no point has any strike-slip boundary between the Pacific and the North American plates been more than ~2000 km long.

With hindsight, it is evident that much of the muddle that exists concerning the TLFZ, both in this book and elsewhere, has arisen because of the sequence of its discovery. It was first documented around the Paleotethys suture in the 1950s. Its southward continuation was not studied until the early 1980s, and the offset Early Cretaceous rocks in the far north of China were not mapped properly until the late 1970s. As a result, it was natural to develop models linking the TLFZ with closure of the Paleotethys.

To conclude, this is a significant but flawed book. Its content will interest specialists in the geology of China, as well as people who are interested in understanding the kinematics of Mesozic plate interactions in and around eastern Asia. The TLFZ will also interest historians of science as an example of the way the order in which information becomes known can dramatically influence its interpretation, and the confusion that can result from an unfavourable sequence of discovery.

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