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Letters to the Editor

Review of Middle East Paleozoic Plate Tectonics

D.A. Ruban, M.I. Al-Husseini and Y. Iwasaki
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The attempt to synthesize the various global and Middle East Paleozoic plate-tectonic reconstruction by Ruban et al. (2007) is a welcome and very ambitious project. It is clearly not easy to decide which of the many conclusions are reliable and which are not. I can only suggest a few minor items, based chiefly on my work in the early Paleozoic.

In Figure 1, it would appear that the authors avoided many of the complexities of the Balkan and Crimea regions.

In Figure 2, the Chukotka region should be associated with the Siberian Platform rather than with Laurentia. The biogeography of most of Alaska has strong Siberian and Uralian affinities but little in common with Laurentia. Only a small part of eastern Alaska, near the Canadian boundary adjacent to the Yukon River, has Laurentian affinities. I do not agree with R. Cocks that Chukotka and allied Alaskan terranes had any relationship with Laurentia in the Paleozoic. Tarim in the early Paleozoic is thought by most Chinese workers to have been adjacent to South China. The Paleozoic position of Moesia is hard to determine since there is little biogeographic evidence other than some Devonian material from the Dobrudja that is similar to Rhenish-Bohemian regions.

On page 39, the authors state that Baltica extended "...to east of the Ural Mountains." I believe this is incorrect, since the Main Uralian Fault involves eastern rocks having nothing to do in the earlier Paleozoic with those in the western Urals, the latter being an integral part of the Russian Platform.

In Figure 4, placing eastern Avalonia next to North Africa involves placing the lower Paleozoic litho- and biofacies (biogeographic materials) of very unlike regions together. Also in Figure 4 the small Kazakh terranes would be better placed between Baltica and Siberia (the so-called "Kara" terrane is probably just a fragment of Siberia). Also, South China, Tarim, Annania and Sibumasu during the early Paleozoic may have been closer to western Australia.

In Figure 5, I suspect that the Rheic Ocean is shown to be too broad as is the Proto-Tethys Ocean. The Gondwana glaciation entered the central Andean region in approximately the Hirnantian interval. Again, I would reposition Sibumasu, Annania and South China close to western Australia.

In Figure 6, I do not know the basis for the Kipchak Arc. The Hun Superterrane looks inadequate to me in many ways. Stringing out the pieces from Tarim to South China does not fit very well with what we know of biogeography in the early Paleozoic.

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Arthur J. Boucot *gained his PhD in Paleontology from Harvard University in 1953. He has worked for the USGS as a Geologist (1949-1967); as a Research Associate with the Smithsonian Institution; as Assistant Professor at MIT (1957-1960); Associate in Paleontology at Harvard University (1957-1960); Associate Professor, Geological Science Division, California Institute of Technology (1966-1968); Research Associate at the Smithsonian from 1967 to present; Professor, Geology Department, Oregon State University (1969-1991); Adjunct Professor, Museum of Natural History, University of Oregon (1971-1976); among others. Arthur has conducted extensive fieldwork on the Paleozoic rocks of the Appalachians, Mid-Continent, and Great Basin, and scattered studies of the entire Siluro-Devonian of the US, adjacent Canada, and northern Mexico. He has authored over 500 publications. He was President of the International Palaeontological Association between 1984-1989, on the Editorial Board of Palaeogeography, Palaeoclimatology, Palaeoecology from 1985-present, and has been Past President and Councilor, International Palaeontological Association, 1989-1992, amongst other achievements. Arthur has been a United States Member, Subcommission on Silurian System of Stratigraphic Commission of International Geological Congress since 1973.*

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I read this paper with great interest and would like to make the following comments regarding the Pontides and Taurides terranes in Turkey. The Carboniferous succession in northern Turkey on the Black Sea coast is closely comparable to the Carboniferous of northwest Europe (e.g. Belgium), much more so than to that of the Ukraine (see Dil and Konyali, 1978). The succession in southern Turkey (e.g. Silifke in the Taurus Mountains) is typically of the "Gondwanan" type (see Demirtasli et al., 1978) and is closely comparable to successions in Afghanistan and Iran (e.g. Central Alborz; see Vachard, 1996), showing the mid Carboniferous hiatus. The successions are not only lithologically similar, but also apparently with regard to faunas and floras, although the published evidence is scarce. The early Carboniferous (Mississippian) near Istanbul is quite different from both (Kaya, 1978).

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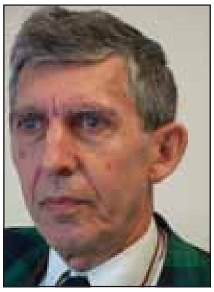

Cor F. Winkler Prins *is a retired head of Palaeontology of the National Museum of Natural History at Leiden (The Netherlands). He received the equivalent of a MS in 1964 and his PhD in 1968 at Leiden University after completing his military service. His research centered on Carboniferous stratigraphy and brachiopods, primarily from the Cantabrian Mountains (NW Spain), but also from other areas such as the Carnic Alps and Algeria. He was strongly involved in the IUGS Subcommission on Carboniferous Stratigraphy and acted for some time as Associate Secretary and later Secretary/Vice-Chairman. In the latter capacity he organised and chaired a field meeting in Turkey in 1978. He is co-editor of the series "The Carboniferous of the World", of which so far three volumes have appeared (on East Asia, Gondwanaland and the former USSR, respectively). As editor of the museums journal "Scripta Geologica" (from 1971 to 2002) Cor was for some time involved (as Associate Secretary) with EDITERRA (the European Association of Editors of Journals in the Earth Sciences). Being interested in the history of the earth sciences, he organised the VII International Symposium 'Cultural Heritage in Geosciences, Mining and Metallurgy: Libraries – Archives – Museums' "Museums and their collections", at the Nationaal Natuurhistorisch Museum, Leiden (The Netherlands), 19-23 May, 2003. He has published some 60 scientific papers. His involvement with the general public through exhibitions lead to his involvement in protecting geological sites and becoming a member of the advisory board of the Dutch Edition of "National Geographic" and of the board of the "Nederlandse Geologische Vereniging", having also served on the boards of many national scientific committees and associations, and on editorial boards of various geological journals. Cor was co-founder of a geological consulting firm "Intergeos". Six fossil taxa have been named after him and he was awarded the knighthood of the Order of Orange-Nassau for his contributions to the international geosciences, Carboniferous stratigraphy in particular.*

From *Yulia V. Mosseichik and Igor A. Ignatiev*
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We would like to express some comments on Ruban et al. (2007) on the basis of the available paleobotanical data that is crucial to evaluate Paleozoic paleotectonic reconstructions, and especially those for the Carboniferous-Permian.

A paleophytogeographical evaluation of the paleotectonic reconstructions is commonly based on assumptions that the development of major botanic-geographical units (phytochoria) and floras of the Earth was mainly autochthonous, because of the long isolation of the continental landmasses. The so-called "mixed floras", i.e. local floras, characterized by mixing of taxa typical for a large phytochorion with plants of some other phytogeographical units, are of special interest. Such a mixture may be interpreted as evidence of the floristic interchange and of the presence of migration routes, land-bridges, and corridors. Consequently, they provide important evidence about the connection of the continental blocks. We need to distinguish the *contact mixed floras*, formed after the above-mentioned floristic interchange and plant migrations between high-rank phytochoria (realms, areas), and the *convergent mixed floras*, which contain elements bearing similarities to the plants of another phytogeographical unit (Ignatiev, 2005). The latter is apparently explained by the origin of the similar morphological structures in plants of the similar landscape-geographical conditions (Berg, 1922).

As for the Late Paleozoic, the reliable paleophytogeographic reconstructions are available since the Mississippian (Early Carboniferous). The paleophytogeographical differentiation, caused by the long isolation of continental masses and their parts, as well as by the presence of thermal belts, existed at least in the Devonian (e.g. Meyen, 1987).

In the global plate tectonic reconstructions presented by Ruban et al. for the Early and Late Carboniferous, Angaraland (Siberia), Gondwana, Laurussia, Kazakhstania, and the Cathasian blocks are shown as isolated landmasses. In general, this corresponds to the paleophytogeographical reconstructions, suggesting the existence of peculiar Angaran, Gondwanan, and Euramerian realms, as well as, probably, Kazakhstanian and Cathasian realms (e.g. Meyen, 1987; Mosseichik, 2006). The position of Kazakhstania in the tropical latitudes and close to the western edge of Laurussia corresponds to the concept of morphological similarity and genetic relations of the corresponding floras (e.g. Meyen, 1987).

As for the European counterpart of the Hun Superterrane, the available paleobotanical data verify the amalgamation of the Western and Central European terranes with Laurussia in the Carboniferous. In particular, the floristic interchange between the Southern and Central-Western European terranes began after the mid-Viséan (mid-Mississippian) (Mosseichik, 2005). The shift of South America towards the Equator in the Late Carboniferous is confirmed with the conclusions by Iannuzzi and Rösler (2000) and Iannuzzi and Pfefferkorn (2002), who suggested the gradual replacement of the temperate *Nothorhacopteris* flora in the north of this landmass by the more thermophilic flora with the Euramerian-like plants. The formation of convergent mixed flora apparently took place in this case.

However, the peculiarities of Early Carboniferous floras of Eastern Kazakhstan and Siberia (Angaraland) indicate the existence of land connections of the territories of present-day Zajsan Lake from one side, and of the Kuznetsk Basin and Rudnyj Altaj from the other side. This was established at least since the Serpukhovian (late Early Carboniferous). The Serpukhovian typical Angaran floras of the Rudnyj Altaj and Kuznetsk Basin include some characteristic Kazakhstan plants (e.g. *Lepidodendron kirgizicum*). Simultaneously, the Angaran species (including *Angaropteridium*) appeared in the Ekibastuz Basin of Kazakhstan. This allows the recognition of the contact mixed floras and implies possible connections between eastern Kazakhstania and the western edge of Angaraland (Vakhrameev et al., 1978; Mosseichik, 2004). A floristic interchange between those territories apparently became possible after their collision at the end of the Early Carboniferous.

The same critical notes apply to the plate-tectonic reconstruction for the Late Carboniferous (Figure 9 in Ruban et al., 2007). It is regrettable that the authors did not take into consideration the reconstructions by Russian geologists (e.g. Kazmin and Natapov, 2000). These reconstructions include crucial palaeobiogeographic data that should be used to constrain future studies.

According to Meyen (1987) and some other authors, the Carboniferous flora of the Cathasian landmasses was similar to and originated from the Euramerian one. A remarkable differentiation of this flora began just in the mid-Carboniferous and then gradually strengthened towards the end of the Permian. Thus, such a remote location of Tarim and North China from the Laurussia as shown on the Devonian paleomaps by Ruban et al. is questionable.

The Late Permian floras of Southern Primor'je and Southern Mongolia are mixed. Although they are dominated by the typical Angaran taxa, they also include Cathasian (e.g., *Lobatannularia*) and even Gondwanan (*Glossopteris*) plants. At the same time, in the Late Paleozoic, the territory of Xingan (Northern North China) belonged to the Angaran Realm. On the contrary, the southern and southeastern regions of North China were populated by the Cathasian *Gigantopteris*-flora until the mid Late Permian. In the Late Tatarian (Lopingian) time, some plants migrated to these regions from the Western Angaraland (Durante and Luvsantseden, 2002). This, consequently, suggests that floras of Angaran and Cathasian realms were isolated from each other by the large Interior Mongolian Ocean, which separated Southern Mongolia from Northern China, until the Late Permian. The closure of this basin resulted in the floristic interchange. Such evidence suggests against the remote position of Angaraland in relation to North China as shown in the article (Figure 10).

In the Late Permian, the Cathasian flora spread over Turkey, Iraq, Syria, and Saudi Arabia. This was considered as evidence of the presence of a belt of thermo- and hydrophylic floras and warm-climate floras along the Paleo-Tethys coast (Meyen, 1987). An isolated position of these territories from the main core of the Cathasian floras in China during the Carboniferous and Permian, as shown in Ruban et al., contrasts with the above-mentioned concept.

In conclusion, the available paleobotanical data would strongly benefit forthcoming paleotectonic constraints.

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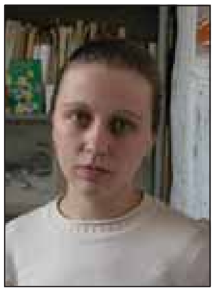

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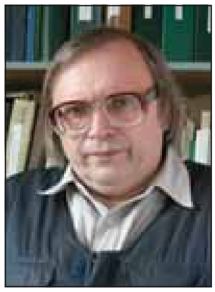

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This paper presents an important review for the Paleozoic plate tectonics of the Middle East, as well as other regions of the Earth.

Regarding the so-called Iranian terranes (North Iran / Alborz, Central Iran / Lut and Sanandaj-Sirjan, as defined in Ruban et al.) I would like to make the following comments about their paleopositions. North and Central Iran, which form most of the Iran, are characterised by: (1) the continuity of Paleozoic sedimentary rocks; (2) common sedimentary evolution including thick sedimentary sequences deposited during the sea-level low-stand of the Gondwanan glaciation; and (3) uniform distribution of biota (Berberian and King, 1981; Leven and Gorgij, 2006). They are therefore considered to have had a common evolution for most of the Paleozoic. Evidence from the metamorphic Sanandaj-Sirjan Zone is controversial despite recent data, which show its affinity to Central Iran (Rachidnejad-Omran, 2002).

Paleobiogeographic studies (Angiolini and Stephenson, in press) of the late Carboniferous (Pennsylvanian) and Early Permian (Cisuralian) biota from the Alborz Mountains, indicate they have a strong affinity with the West Tethys and Uralian Provinces of Shi (1998). The same is true for Central Iran, suggesting paleopositions at low latitudes. Paleomagnetic constraints, based on published and new data (Muttoni, personal communication), indicate that they were located south of the Equator in the Paleozoic, reaching it only in the Late Permian (Lopingian).

In the Early Devonian, Ruban et al. Figure 7 shows Northwest and Central Iran at 20° to 30° south of the Equator, and this is consistent with Devonian paleomagnetic data indicating 40° south. In the Late Permian (Figure 10) Northwest and Central Iran are shown at 15° south which is consistent with paleomagnetic indicating 18° south for the Middle Permian and an equatorial position for the Permian-Triassic boundary.

In considering climate model and surface currents, I am convinced that in Pennsylvanian-Cisuralian (late Carboniferous-Early Permian) time the Iranian terranes were located at low latitudes (20° south) along the Gondwanan margin, close to the northern corner of Arabia. The apparently contradictory northerly faunal evidence can be explained by the fact that they were involved in a warm current gyre, while Gondwana and the Cimmeria were affected directly or indirectly by the Gondwanan glaciation (Angiolini et al., submitted).

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Comment on the "Review of Middle East Paleozoic Tectonics"

A.J. van Loon

Introduction

The recent review of Middle East Paleozoic plate tectonics (Ruban et al., 2007) should be considered as a benchmark that may serve as a highly valuable reference work for years to come. Reviews like this require a tremendous effort in literature search, as well as in hypothesizing to fill in the gaps that have been left by earlier researchers. In addition, many research results are mutually contradictory, whereas other results need a lot of interpretation because they are ambiguous, for instance with respect to the stratigraphic units chosen. This implies that the authors of a review like that by Ruban et al. must necessarily be prudent in their conclusions. In some cases, precise conclusions cannot even been drawn. An example is found in the Introduction, where Ruban et al. state that "Correlation of the sedimentary core complexes ...suggests that all of these terranes share a common ancestry *during some time* in the Paleozoic Era" (my italics). It is obvious that the authors had insufficient reliable data about the development of plate tectonics during the beginning of the Paleozoic to be more specific regarding the time frame.

This is due to a well-known problem in the Earth Sciences: *the historical perspective*. The further back one goes into the geological past, the less data (in the form of rocks and their content) remain and the more difficult their interpretation is, due to alterations (such as those caused by metamorphosis, orogenesis or long-lasting pedogenesis) that may occur in the course of the geological time. For this reason it is of utmost importance to know how the authors have composed their review, but their approach is, unfortunately, not made really clear.

Historical Perspective

The development of an area – and therefore also the plate-tectonics history – in the course of the geological time can, in principle, be handled in two ways. The first one is to start at a certain point in time and to describe the development from that time onwards. The second approach is to start from the present (or any point in time), and to work backwards. Obviously, the first type of approach is the most logical, the easiest to follow for the readers, and the most in accordance with historical reviews ("because this process took place, these consequences followed"). In practice, however, this approach is commonly impossible in the Earth Sciences. Geologists are commonly forced to work with a limited amount of exposed rock, and only if they have collected sufficient data to put them in a logical framework, they can find out what process or conditions must have been responsible for the features that are shown by the geological record. Geologists therefore tend to work backwards in time. This has happened from the very beginning of the Earth Sciences.

It is not clear from the review by Ruban et al. which approach they have followed. They present their review in a geochronological order, but this does not necessarily imply that they did not prepare their overview backwards in time. It is important to know this, however, because their approach may have consequences for the reliability of the beginning of their plate-tectonics reconstruction. They present this reconstruction from the beginning of the Paleozoic onwards, so their starting point must be (more or less) the transition from the Ediacaran (latest Proterozoic) to the Cambrian. In fact, they consider this Ediacaran/Cambrian transition as an interval of Rodinia breakup that lasted from about 560 Ma to 530 Ma (their figure 3), so that their effective reconstruction starts at about 530 Ma.

Continental Configuration

The reconstruction of the plate-tectonics development obviously depends on the configuration of the then-existing supercontinents, Gondwana, Laurussia and Pangea (Ruban et al., p. 39). This implies that the reliability of the authors' reconstruction of the plate-tectonics development strongly depends on the configuration of these supercontinents. Unfortunately, the authors hardly pay attention to the numerous controversial hypotheses concerning this configuration – and the drift of the supercontinent(s) – during the Neoproterozoic. Whereas much is known about the position (and movements) of the supercontinents during the second half of the Paleozoic so that the overview (and more importantly, the synthesis) of Ruban et al. can be considered fairly precise for the last 150 million years of the Paleozoic, the data for the first 150 million years are so controversial that a discussion about the precise approach followed by the authors in selecting what they consider as the most reliable (i.e. most likely correct) data, would have increased the value of their monumental overview significantly.

Relationship with Other Problems

A thorough reconstruction for the plate-tectonics development during the Neoproterozoic and earliest Cambrian would be most welcome also for other reasons. There is, for instance, much discussion about the Neoproterozoic glaciations. Did a "Snowball Earth" situation exist, or are the hypotheses about the existence of such exceptional conditions (e.g. Crowell, 1957; Harland and Bidgood, 1959; Meert and Van der Voo, 1994; Sohl et al., 1999) due to misinterpretation of the paleomagnetic data indicating the continents' exact position (Li, 2000), and/or to a different tilt of the Earth's rotational axis (e.g. Williams et al., 1998; Williams, 2004; Young, 2004)? More precise (and reliable) data about the plate-tectonics development within the framework of the reconstruction of the continental drift might, in addition, also help to shed more light on the sudden explosive development of the Ediacara fauna, which now is explained by a wide variety of environmental conditions and continental configurations (Narbonne and Gehling, 2003; Squire et al., 2006; Canfield et al., 2007).

Summarizing, it seems that the starting point of Ruban et al. poses more questions than it provides answers. It should be emphasized, however, that this magnificent overview becomes increasingly more accurate and reliable for each subsequent phase of the Paleozoic Era. An equally accurate and precise reconstruction for the Cambrian as for the Permian will, obviously, not be obtained with the data and methods that are currently available. This highly interesting review would gain much value, however, if the authors could prepare a similar contribution about the transition between the Proterozoic and the Cambrian, with a clear discussion about their arguments for their choice from the numerous controversial data that are now found in the literature.

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