The Ordovician ostracod *Saltite* from Argentina and its relation to Australia

ROGER SCHALLREUTER & INGELORE HINZ-SCHALLREUTER

ORDOVICIAN ostracodes from South America are poorly known. Since 1981, when the state of knowledge was reviewed by the first author (Schallreuter 1981), some new information has been published (see Schallreuter 1996, p. 139-141; Schallreuter 1999; Schallreuter & Hinz-Schallreuter 1999; Salas 2002a, b).

The presence of ostracodes in the Ordovician at San Bernardo Hill, Salta, was recognised by Frenguelli already in 1937 (p. 544-545). Among other fossil groups, he mentioned ostracodes (*Beyrichia*) from “... arcillo-esquistos de Ordovicico”. Harrington (1938, p. 140-141) assigned these specimens together with additional material collected by A. Erichsen to *Drepanellina erichseni* and *Zygobolba asapha*. By contrast, de García & Proserpio (1976) established the two new genera *Bernardite* and *Saltite* for the abovementioned species, supplemented by the description of the new species *B. longisulcus*, *Saltite saltensis* and a third new genus and species (*Nortite elongatum*). New material collected by us in 1990 comprises the whole spectrum of these described taxa in sufficient quantities and preservation to allow the recognition of outer shell characters contrary to previous taxonomic studies which were based on information of internal moulds only. The large number of *Saltite* representatives enabled a detailed morphological analysis and the identification of *Bernardite* and *Nortite* as synonyms of *Saltite*.

**LOCALITY AND AGE OF THE FAUNA**

Ostracod-bearing levels in the Ordovician of Argentina, the so-called *Sanbernardaspis* levels (Aceñolaza 1973) belong to the San Bernardo Hill section located directly in the city of Salta, province of Salta, NW Argentina (Fig. 1). The San Bernardo Hill section is part of the so-called Mojotoro Formation which has a total thickness of about 1500 m comprising sediments from...
Tremadoc to Llanvirn (Aceñolaza 1973, p. 133). According to Harrington (in Harrington & Leanza 1957), the San Bernardo Hill section divides into the basal Aspero Formation of approximately 190 m and the overlying San Bernardo Formation (SBF) of some 470 m thickness (see also Turner 1970, p. 1041). By contrast, Aceñolaza (1973) documented an exposure of 315 m at San Bernardo Hill, which corresponds to the lower part of the San Bernardo Formation which is of Arenigian age. He distinguished the lithostratigraphic units shown in Table 1 with their associated fauna (Aceñolaza 1973, p. 133-134).

The lowermost part of the SBF of Salta (Eastern part of the Eastern Cordillera) belongs to the uppermost Tremadoc (Moya 2003, fig. 2). Monteras & Moya (2003) considered a late upper Tremadocian age for the lowermost part of the SBF based on evidence from graptolites. They described the SBF as follows: “silty shales, siltstones and fine-grained olive-green wackes deposited in a marine environment of transitional facies between the inshore and offshore shelf. Sandstone and conglomerate beds assigned to storm and gravity flow deposits are interbedded in the succession of shales and fine wackes”.

### MATERIAL AND METHODS

The material described herein comes from the two thickest units of 84 and 97 m of dark green limestones with intercalated quartzites or shales, respectively (see Table 1). Ostracodes occur only in single beds but in large quantities and may completely cover the bedding planes. They also are associated with brachiopods as seen in Figure 2B. Brachiopods were not mentioned by Aceñolaza (1973) and the isolated nature of the rock does not permit a precise assignment to any horizon mentioned in Table 1.

The ostracodes are only preserved as steinkerns and/or external moulds. Casts from external moulds were prepared to study outer gross morphological characters. They are documented by stereopair SEM photography. The micrographs were made in Hamburg by the first author. The material is housed under the nos. 343 at the Institute of Geography and Geology, Ernst Moritz Arndt University, Greifswald (GG).

<table>
<thead>
<tr>
<th>Thickness</th>
<th>Lithology</th>
<th>Faunal components</th>
</tr>
</thead>
<tbody>
<tr>
<td>35 m</td>
<td>Reddish and white quartzitic sandstone commonly with cross bedding structures and ripple marks</td>
<td></td>
</tr>
<tr>
<td>34 m</td>
<td>Stratified green-yellowish shales, interbedded with thin quartzite layers</td>
<td><em>Megalaspidella</em> and <em>Thysanopyge</em> (trilobites)</td>
</tr>
<tr>
<td>39 m</td>
<td>Quartzitic sandstones with many layers of massive limestones</td>
<td></td>
</tr>
<tr>
<td>97 m</td>
<td>Limestones and shales, dark green, micaceous, stratified</td>
<td>trilobites, graptolites, molluscs, and levels with ostracodes</td>
</tr>
<tr>
<td>26 m</td>
<td>Stratified dark-green limestones</td>
<td></td>
</tr>
<tr>
<td>84 m</td>
<td>Dark-green limestones with ripple marks and intercalations of quartzites</td>
<td>trilobites, graptolites, and ostracodes frequent</td>
</tr>
</tbody>
</table>

*Table 1. Thickness and faunal content of the lithological units of the lower San Bernardo Formation at San Bernardo Hill section.*
SYSTEMATIC PALAEONTOLOGY

Suborder PALAEOCOPA Henningsmoen,1953 emend. Martinsson,1955
Superfamily TETRADELLOIDEA Swartz,1936
Family SOANELLIDAE Kanygin,1971

Saltite de García & Proserpio,1976


Type species. Drepanellina erichseni Harrington,1938.

Diagnosis. Medium-sized, quadrilobate. Lobes broad, sulci narrow and slit-like; L3 most strongly developed, L1 being second strongest lobe. Velar sculpture lacking.

Occurrence. Argentina; Arenig.

Comparison. Saltite is very similar to Eopilla Schallreuter,1993 from the upper Tremadoc of Australia. Both are quadrilobate; in both L3 is the strongest and L1 the second strongest lobe. Both lack distinct adventral sculptures. Saltite differs from Eopilla in having broad lobes and slit-like sulci. The lobes in Eopilla are small and ridge-like and the sulci are correspondingly broader.

Remarks. Saltite and Eopilla are monotypic genera. It is possible that Eopilla could be regarded as a subgenus of Saltite, but this is presently unclear.

Saltite erichseni (Harrington,1938) (Figs 2-3)

1937 Beyrichia (partim?); Frenguelli, p. 544-545.
1938 Drepanellina erichseni sp. nov.; Harrington, p. 141, 255-256; pl.3, figs 18, 20-21.
1957 “Drepanellina” erichseni Harrington; Harrington & Leanza, table 3 (p. 31).
?1957 “Zygobolba” asapha Harrington; Harrington & Leanza, table 3 (p. 31).
1973 Drepanellina; Burret, p. 179.
?1973 Zygobolba; Burret, p. 179.
1976 Drepanellina ericksont (sic) Harrington (1938); de García & Proserpio, p. 558, 560-561, 563.
1976 Saltite erichseni (Harr. 1938); de García & Proserpio, p. 558, 560-561, 563; pl. 1, figs 3a-b.
?1976 Bernardite longisulcus n. sp.; de García & Proserpio, p. 559-560, 563; pl. 1, figs 1a-b.
?1976 Bernardite asapha (Harr.); de García & Proserpio, p. 559-560,563; pl. 1, fig. 2.
?1976 Saltite saltensis n.sp.; de García & Proserpio, p. 561,563; pl.1, figs 4a-b.
?1976 Nortite elongatum n.sp.; de García & Proserpio, p. 561-563; pl. 1, fig. 5.
1981 “Drepanellina” erichseni Harrington; Schallreuter, p. 10.
?1986a Bernardite asapha (Harrington, 1938A); Kempf, p. 109.
1986a Drepanellina erichseni Harrington, 1938A; Kempf, p. 323.
1986a Saltite erichseni (Harrington, 1938A); Kempf, p. 671.
1986a *Zygobolba asapha* Harrington, 1938 A; Kempf, p. 760.

1986b *Bernardite asapha* (Harrington, 1938A); Kempf, p. 66.

1986b *Zygobolba asapha* Harrington, 1938A; Kempf, p. 66.


1986b *Drepanellina erichseni* Harrington, 1938A; Kempf, p. 207.

1986b *Saltite erichseni* (Harrington, 1938A); Kempf, p. 207.


1987 *Drepanellina erichseni* Harrington, 1938A; Kempf, p. 209.


1987 *Bernardite asapha* (Harrington, 1938A); Kempf, p. 640.


1987 *Saltite erichseni* (Harrington, 1938A); Kempf, p. 640.


1996 *Bernardite asapha* (Harrington, 1938); Schallreuter, p. 140.

1996 *Saltite erichseni* (Harrington, 1938); Schallreuter, p. 140.

1996 *Bernardite longisulcus* de Garcia & Proserpio, 1976; Schallreuter, p. 140.

1996 *Saltite saltensis* de Garcia & Proserpio, 1976; Schallreuter, p. 140.

1996 *Nortite elongatum* de Garcia & Proserpio, 1976; Schallreuter, p. 140.

Holotype. “Moldo” (steinkern?) of a right valve, P.I. 002.

Type locality. Cerro San Bernardo, Salta, NW Argentina.


Material. Several pieces of rock with hundreds of steinkerns and external moulds (for example, see Fig. 2).

Diagnosis. Length at least up to 1.12 mm. Sulci slit-like with S1 and S2 extending straight and perpendicular to straight hinge-line, S3 bow-shaped with concave side being anterior; S2 of nearly even width along its length.

Description. Outline almost semicircular and slightly postplete. Dorsal margin straight. Maximum length at about mid-height, maximum convexity at about the centre of L3 in the posterior half of the valve. Free margin evenly developed, lacking any distinct adventral sculpture. Lobation consists of four strong lobes. L1 is crescent-like. It is the broadest lobe and extends to the anterior margin. L2 is comparatively long but rather narrow. Unlike all other lobes it does not reach the dorsal rim. L3 is the highest lobe and may also project beyond the hinge-line. It is developed as mirror-image to L1, being roughly crescent-like and tapering towards the dorsal margin. The posteriormost lobe (L4) is not as broad as L1 and has an indistinct transition towards the posterior lateral surface. All sulci are rather narrow and slit-like. S1 and S2 are nearly straight and perpendicular to the dorsal margin with S2 being the longest sulcus. S3 appears sickle-shaped. A distinct outer surface sculpture is not observable; the rough appearance of the casts is due to sediment particles stuck to the external moulds.


SYSTEMATIC POSITION OF ORODOVICIAN OSTRACODS FROM SOUTH AMERICA

De Garcia & Proserpio (1976) revised the two species *Drepanellina erichseni* and *Zygobolbina asapha* which were originally erected by Harrington (1938). The authors described three additional new species for which they established three new genera. However, their systematic studies were based exclusively on steinkerns which generally deliver information about the inner shell surface, i.e., lobal and sulcal features, and only rarely also of ornamental characters. In ostracodes, ornamental features are usually restricted to the outer shell surface so that the morphology of steinkerns and external moulds can be rather different. Therefore, it is of utmost importance in studying material lacking preserved shell substance to not only examine internal moulds but also casts of external moulds (Schallreuter & Krůta 1988, p. 100). With regard to de Garcia & Proserpio’s material, not only their genera but also their species seem to be all synonymous. The genus *Bernardite*, for example, is distinguished by the shape and location of L1 and L2, *Nortite* merely by its elongate shape (de Garcia & Proserpio 1976, p. 561).
De García & Proserpio (1976, p. 559) assigned all their genera to the family Quadrijugatoridae Kesling & Hussey, 1953, superfamily Hollinacea. Jaanusson (1957, p. 22) considered this family to be a member of the Eurychilinacea, suborder Palaeocopa. Subsequently, Henningsmoen (1965, p. 391) placed the family within the superfamily Drepanellacea the Quadrijugatoridae were assigned to the Binodicopa. However, *Saltite* has a gross morphology completely different from Binodicopa. Although their lobation resembles some palaeocopes, certain differences are quite obvious. Palaeocopes are usually characterised by both a velum and a marginal sculpture. In contrast, a velar sculpture could not be observed on *Saltite*. Although de García & Proserpio described a velar sculpture, their illustrations lack any reliable evidence for velar and/or marginal sculptures. Also, investigations of the ample material on hand do not indicate the presence of a velum. The insufficient preservational status of the specimens does not allow precise statements about possible marginal sculptures or sculptures of the contact margin, respectively.

With its occurrence in the Lower Arenig, *Saltite* is one of the oldest known ostracodes. For the reasons outlined above, *Saltite* has been placed within the palaeocope family Soanellidae (Schallreuter & Hinz-Schallreuter 2004, p. 206), which are quadrilobate to unisulcate and non-dimorphic. Their representatives are inequivalved to nearly equivalved with accordingly different sculptures of the contact margin.

The quadrilobate or trilobate palaeocopes described by Přibyl (1984) from the Llanvirn of Bolivia (*Quadrilobella simplicata*, *Sibiritella? angustilobata* and *Zygobolboides tuctapariensis*) are also non-dimorphic. These three genera all belong to the family Soanellidae (Schallreuter & Hinz-Schallreuter 2004).

The quadrilobate palaeocope from the Middle Ordovician of Peru originally assigned to the genus *Tetradeilia* by Newell & Tafur (1944, p. 544) was considered reminiscent of the Bolivian *Cerinella* Přibyl, 1966 and *Tallinnella*-like forms in general by Siveter (in Hughes et al. 1980, p. 14). Since dimorphism is unknown from this taxon, it may be also a soanellid, tentatively assignable to *Quadrilobella?* sp.

**Palaeobiogeographic and Phylogenetic Significance of the San Bernardo Fauna**

Members of the Soanellidae are known from Siberia, China, North and South America as well as from Australia. In Siberia, soanellids are fairly common, but the Siberian forms are commonly strongly inequivalved unlike the soanellids from Gondwana and may therefore represent a separate subfamily. With regard to outer gross morphology, the Siberian representatives probably differ from other soanellids in their contact marginal sculptures, which are, however, insufficiently known.

The Australian soanellid *Eopilla* Schallreuter, 1993 (Fig. 4) from the lower Emanuel Formation (upper Tremadoc) at Prices Creek, northern Western Australia is the oldest known Ordovician ostracod from Australia and shows closest palaeogeographic and palaeobiologic affinities to *Saltite*. They share the following characters: quadrilobation with L3 being the strongest and L1 being the second strongest lobe; a distinct
adventral sculpture is not developed and velar dimorphism is therefore lacking. Differences are in the development of broad lobes and slit-like sulci (Saltite) and narrow lobes and broad sulci (Eopilla).

Originally, the non-dimorphic Eopilla was assigned to the binodicope subfamily Pillinae – a common group in both Argentina and Australia (Schallreuter 1993, 1996; Salas 2002a). Their representatives are marked by the typical binodicope pattern supplemented by a third posterior ridge-like lobe. Eopilla, however, is distinguished from true pillines by the development of a distinct fourth lobe in the posterior part of the valve. This was the reason Schallreuter & Hinz-Schallreuter (2004, p. 206, 208) suggested an assignment of the genus to the palaeocope family Soanellidae, which is characterised by quadrilobate ostracodes lacking velar dimorphism. This is confirmed by the present study documenting the obvious similarity between Eopilla and Saltite combined with an increased knowledge about palaeocope phylogeny.

Eopilla and Saltite are probably members of different evolutionary lines, which derived from a common ancestor with unreduced, equally broad lobes and sulci. In Eopilla, the lobes became reduced and ridge-like, while in Saltite, the sulci became reduced and slit-like. The suggested common ancestor of both taxa must have occurred in the Lower Tremadoc or in the Late Cambrian. Therefore, the origin of the palaeocopes must extend back as far as to the Lower Tremadoc if not to the Late Cambrian.

In both South America and Australia, dimorphic palaeocopes are lacking throughout the Ordovician. The same is true of the quadrilobate palaeocopes described by Přibyl (1984) from the Ordovician of Bolivia. The quadrilobate Tetradella sp. from the Upper Llanvirn Contaya Formation of Peru (Newell & Tafur 1943, 1944) was reexamined by Siveter (in Hughes et al. 1980) and does not reveal adventral sculptures and ventral parts in the available material so that dimorphism could not be verified. By contrast, dimorphic palaeocopes occur already in the Billingen (Arenig) of Baltica with Hithis proximus Melnikova, 1999.

The phylogenetic relations between non-dimorphic and dimorphic palaeocopes are still under discussion. Henningsmoen (1965, p. 384) suggested that palaeocopes might include possible non-dimorphic offshoots. Alternatively, soanellids might be regarded as non-dimorphic ancestors of Palaeocopa s.str. Loss of dimorphism by paedomorphosis was a suggestion by Siveter (1985), who based his hypothesis on Ametobeyrichia schizopyge Siveter, 1985, a beyrichiomorph without cruminal dimorphism. The latter taxon has, however, never been described and therefore, is a nomen nudum.

CONCLUSIONS
Reexamination of Saltite erichseni based on new material and application of casting methods enabled a detailed study of gross morphological features for the first time. Further, it is shown that a number of contemporaneous nominal ostracode taxa described from Argentina, such as Zygobolba asapha Harrington, 1938, Bernardite de García & Proserpio, 1976, Bernadite longisulcus de García & Proserpio, 1976, Saltite saltensis de García & Proserpio, 1976, Nortite de García & Proserpio, 1976, Nortite elongatum de García & Proserpio 1976) in fact belong to the genus Saltite.

Comparison with other Ordovician ostracods showed closest systematic affinities between Saltite and the Australian Eopilla accompanied by their palaeogeographic proximity.

Saltite and Eopilla are representatives of the family Soanellidae, which comprises non-dimorphic palaeocopes. The phylogenetic relations between non-dimorphic and dimorphic palaeocopes, i.e., between soanellids and palaeocopes s.str., are still unknown. Whether or not soanellids represent ancestral forms, are palaeocope offshoots, or result from paedomorphosis is still being discussed.

ACKNOWLEDGEMENTS
The authors thank Florencio Gilberto Aceñolaza for guidance to the fossil locality at San Bernardo Hill during a field trip in 1990, and anonymous reviewers for valuable comments and references to special literature which improved the manuscript significantly.

REFERENCES


García, E.R. De & Proserpio, C., 1976. Ostracodos del...
Ordovician (Arenigiano) del Cerro San Bernardo - Provincia de Salta Republica Argentina. Actas VI. Congreso geologico Argentino 1, 557-563.


of Ostracod Shells 19(2) 10, 37-40.


