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NOTA PALEONTOLÓGICA

Remarkable *Cruziana* beds in the Lower Ordovician of the Cordillera Oriental, NW Argentina

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Introduction

Upper Cambrian - Lower Ordovician strata of the South American Central Andean Basin contain abundant and well-preserved trace fossil assemblages that have been mostly studied after the mid 1960´s (Borrello, 1966; Ramos, 1973; Aceñolaza, 1978; Alonso and Marquillas, 1981; Toro *et al*., 1988, 1990; Mángano *et al*., 2001; Aceñolaza and Aceñolaza, 2002 with references). Early reports of these fossils were provided by d´Orbigny (1842), who described Bolivian material from the surroundings of Zudañez (Cochabamba and Chuquisaca departments) and introduced *Cruziana*, an ichnogenus that nowadays is one of the most intriguing trace fossils.

Lower Paleozoic *Cruziana* are mostly regarded as trilobite crawling exite-produced traces, and due to their striking morphology have provoked many remarkable papers focusing on different aspects of their production, preservation and variability (*e.g*., Seilacher and Crimes, 1969; Crimes, 1970, 1975 Seilacher, 1970; Crimes and Marcos, 1976; Bergström, 1976, 1979, 1981; Pickerill and Fillion, 1983; Fillion and Pickerill, 1990).

Extraordinary well-preserved *Cruziana* pavements have been recently located in Lower Ordovician strata of the Sierra de Zenta in Jujuy province (northwest Argentina). The traces are assigned to the "*rugosa* group" of Seilacher (1970) and come from the upper part of the Santa Victoria Group, close to the Abra Blanca locality (figures 1, 2, 3.B-I).

The objective of this paper is to present this outstanding new ichnofossiliferous locality, advancing some results of an interdisciplinary project that is being carried out in the Sierra de Zenta of northwest Argentina.

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The ichnogenus Cruziana *d`Orbigny, 1842*

Cruziana is mostly represented by a bilobate and elongated furrow covered by transverse or herringbone-shaped ridges. Traces may be marginated by lateral outer zones with or without ridges (Häntzschel, 1975; Pickerill *et al*., 1984; Fillion and Pickerill, 1990). The ichnogenus ranges from the Lower Cambrian to the Triassic, and has been reported from a varied spectrum of paleoenvironments, ranging from typical shallow water marine to freshwater settings (Crimes, 1987; Bromley and Asgaard, 1979; Seilacher, 1985).

Seilacher (1970) grouped different ichnospecies of *Cruziana* by means of their morphological and biostratigraphical setting. The "*rugosa* group" displays a prevalence of long ploughings over resting tracks, and includes *C. rugosa* d´Orbigny, *C. furcifera* d´Orbigny, *C. goldfussi* (Rouault) and *C. barriosi* Baldwin. *Cruziana rugosa* d´Orbigny stands out as its most remarkable element, being characterized by strong corrugations across the lobes and numerous sharp scratches indicating up to 12 subequal claws for each endopodite (figure 2) (Seilacher, 1970).

The "*rugosa* group" is widely distributed in the perigondwanan realm: Bolivia, Argentina, Newfoundland, Portugal, Spain, France, Wales, Turkey, Jordan, Libya, Iraq, Saudi Arabia, Afghanistan, and China (Seilacher, 1970, 1992; El-Khayal and Romano, 1988; Seilacher *et al*., 2002; Aceñolaza and Aceñolaza, 2002). The group has repeatedly been the subject of Lower Paleozoic literature, and there is still considerable debate regarding the distinction of its different ichnospecies (Fillion and Pickerill, 1990). Although some authors have supported an ichnosubspecific assignment (Seilacher, 1996), we prefer to provisionally retain the individual ichnospecies, fol-

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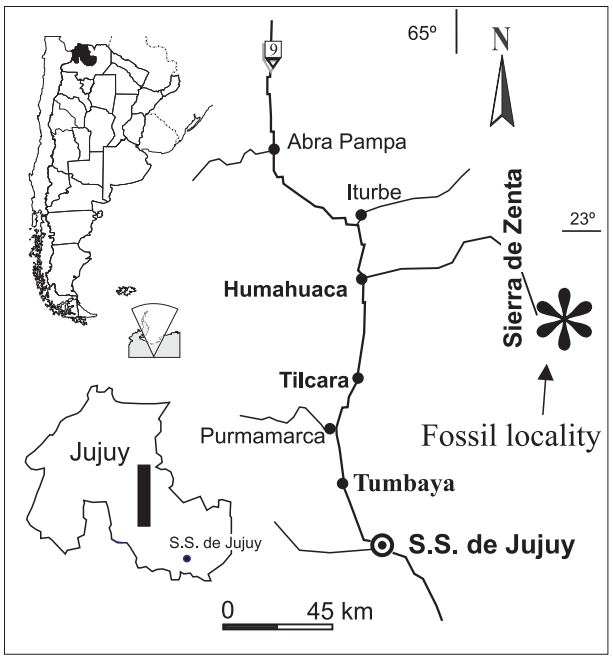

Figure 1. Localition map of fossiliferous outcrop (asterisk)/*Mapa de ubicación de la nueva localidad (asterisco)*.

lowing the insightful discussions by Pickerill *et al*. (1984), Durand (1985) and Fillion and Pickerill (1990). A detailed systematic analysis of over 1.000 well preserved samples is being carried out within the current project.

Most Lower Paleozoic *Cruziana* are regarded as trilobite traces, although some may have been produced by different types of arthropods, some brachiopods, aglaspidis or even vertebrates (Seilacher, 1970; Bromley and Asgaard, 1979; Fisher, 1978; Shone, 1979; Fillion and Pickerill, 1990). Asaphacean trilobites have been suggested by several authors as possible producers of the "*rugosa*" group (Bergström, 1973; 1976; Mángano *et al*., 2001; Aceñolaza, 2003), but unfortunately, to date no trilobites have been found associated with the trace fossils in the new locality.

Sedimentology and the *Cruziana* association of Zenta

Ordovician strata in the Sierra de Zenta display a thick sequence where sheet-like and ribbon-like sand bodies alternate with muddy intervals. Most sand bodies are almost completely altered by bioturbation. Trace fossils are better preserved in the less bioturbated mudstone intervals. The latter are characterized by a dominantly heterolithic sequence, in which silty massive packages alternate with sandy beds where most *Cruziana* pavements are found.

Sandy intervals are, with the exception of a faint stratification, depleted of almost all primary depositional structure due to bioturbation. Sand bodies show a coarsening-up grain size tendency and fragmented shell debris lags are frequent in these units.

In spite of the turbidite-like appearance, all the sequence has been interpreted as deposited within an outer shoreface environment with frequent shoaling bars, becoming shallower towards the top. In addition, there is a remarkable absence of important unconformities in the sequence. Strata display a thick shoreface succession, suggesting a quite stable tectono-eustatic framework for Tremadocian-Arenig times.

Traces represent mostly shallow crawling open furrows, but frequent deep steeply walled specimens were observed, some of them regarded as true burrows in a same manner that mentioned earlier for other Gondwanan localities (*e.g*., Seilacher, 1955; 1970; 1982; Baldwin, 1977; Goldring, 1985). Traces are preserved in medium to fine-grained sandstone beds up to 40 cm thick as concave epireliefs and undertracks, types of preservation that were not previously described from the Lower Paleozoic of South America. The last ones usually display washed out surfaces and generally do not show fine details as those preserved as convex hyporeliefs. Associated traces are represented by several forms of *Lockeia*, *Skolithos*, *Monomorphichnus* and *Dimophichnus*.

Brief description of the material

Part of the material described in this paper is housed in the paleontological collections of the Facultad de Ciencias Naturales e Instituto Miguel Lillo of the Universidad Nacional de Tucumán (PIL 15.099-15.101). The sample figured in 3 C, E is housed and exhibited at the Museo Argentino de Ciencias Naturales "Bernardino Rivadavia" of Buenos Aires (MACN Icn 2253).

Cruziana furcifera d´Orbigny 1842 (Cf in figures 3 D-F, I)

Description and remarks. Large-to mid- sized traces with inner lobes and lacking outer lobes. Mostly bifid scratch marks are developed regularly over lobes, reaching the median groove with an acute angle of 15º to 65º degrees. Criss-crossing is recognized close to the median groove, producing faint rhombic patterns in some material, as also described previously by Fillion and Pickerill (1990) and El-Khayal and Romano (1988). Width of traces varies from 30.3 to 70.6 mm, depth up to 60 mm, and length reaches in some specimens up to 800 mm. Minor sectors of many long specimens display a transitional morphology to *C. rugosa*. This is a common ichnospecie, representing 15 % of the total analyzed traces.

Cruziana goldfussi (Rouault 1850) (Cg in figures 3 C, E, H)

Description and remarks. Mid- to small-sized Cruziana displaying fine and relatively parallel scratch marks along the lobes. Inner and outer lobes can be distinguished in most of the samples. Width of traces range between 18.4 to 75.2 mm. Outer lobes represent approximately 5-10 % of trace width. Scratches reach the median groove at angles varying from 20º to 70º. The presence of faint corrugations by sectors in some of the samples resembles the morphology of *C. rugosa*; while rare faint criss-crossing of

scratch marks in certain samples is reminiscent of *C. furcifera*. *Cruziana goldfussi* represents approximately 18% of the total analyzed samples.

Cruziana rugosa d´Orbigny 1842
(Figure 2; Cr in figures 3. C-H)

Description and remarks. High relief large and robust bilobed traces up to 78 mm wide. Traces display well-developed scratch marks and a moderately deep irregular median furrow (up to 15 mm deep). Large ribbon-like traces are frequent, reaching a length of 400 to 500 mm. Transverse coarse corrugations characterize this ichnospecies, developed by sets with 8 to 15 scratch marks, each one representing individual appendage impressions. As previously mentioned by several authors (*e.g.*, Pickerill *et al*., 1984; Fillion and Pickerill, 1990; Mángano *et al*., 2001; Aceñolaza and Aceñolaza, 2002), our material transitionally passes into *C. furcifera* d`Orbigny, while fewer transitions to *C. goldfussi* Rouault were also recorded.

Cruziana rugosa d`Orbigny (1842) is the type species of the ichnogenus and represents almost a 70 % of the traces assigned to *Cruziana* in the outcrop.

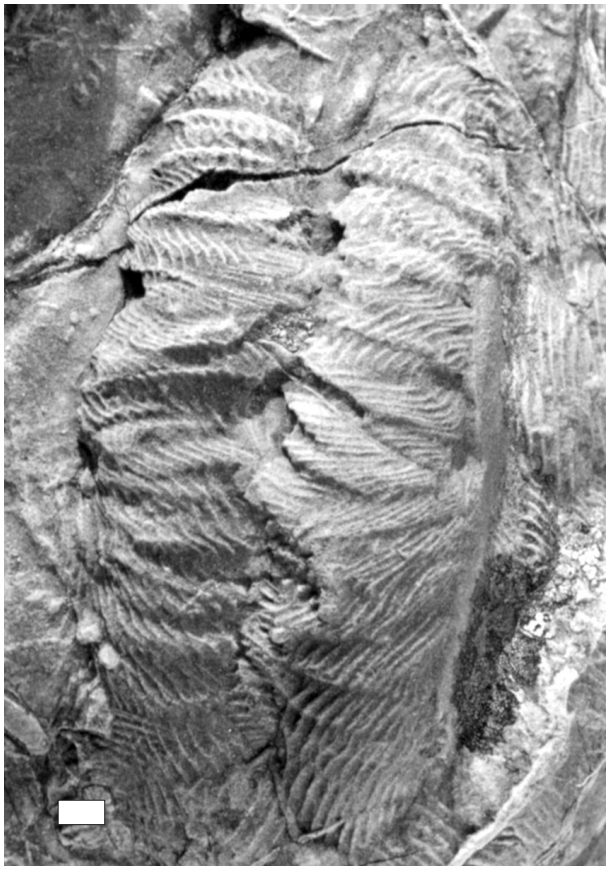

Figure 2. Isolated steeply walled sample of Cruziana rugosa d`Orbigny displaying characteristic strong corrugations across the lobes with numerous and sharp scratches (Scale 1 cm; PIL 15.099)/ *Ejemplar de* Cruziana rugosa *d`Orbigny con sus características corrugaciones transversales y marcas lobulares (Escala 1 cm; PIL 15.099).*

Final comments and conclusions

The "*Cruziana* stratigraphy" concept is recognized as an effective biostratigraphic method for field-work dating, specially in the non-fossiliferous shallow siliciclastic platforms of Gondwana (Crimes, 1969; 1975; Seilacher, 1970, 1992; Baldwin, 1977; Crimes and Marcos, 1976; Pickerill *et al*., 1984).

In NW Argentina the association *C. semiplicata* / *C. furcifera* characterizes late Cambrian-Tremadocian beds, while elements of the "*rugosa* group" (*C. rugosa*, *C. goldfussi* and *C. furcifera*) are restricted to the upper Tremadocian-Arenig as mentioned by Mángano *et al*. (2001) and Aceñolaza and Aceñolaza (2002). Although early papers have provided, with a limited number of samples from discontinuous sections, some data about the *Cruziana* stratigraphy of the Central Andean Basin (*e.g.*, Mángano *et al*., 2001), no integrated biostratigraphical-sedimentological analysis with abundant traces have been done in the South American Gondwanan margin. As pointed out by Seilacher (1970) and El-Khayal and Romano (1988), "*Cruziana* stratigraphy" is reliable only if research is done over assemblages with numerous traces.

The quality and quantity of traces, and the stratigraphical continuity of the sequence of the Sierra de Zenta (including the Tremadocian/Arenig transition), will give a better sight of the biostratigraphy in the Lower Ordovician strata of Northwest Argentina. Most sequences of the Cordillera Oriental are fragmentary due to its complicated tectonic setting, thus the Lower Ordovician of Zenta represents a unique field laboratory to understand the sedimentary history of the basin. Promising results are expected from this new outstanding locality.

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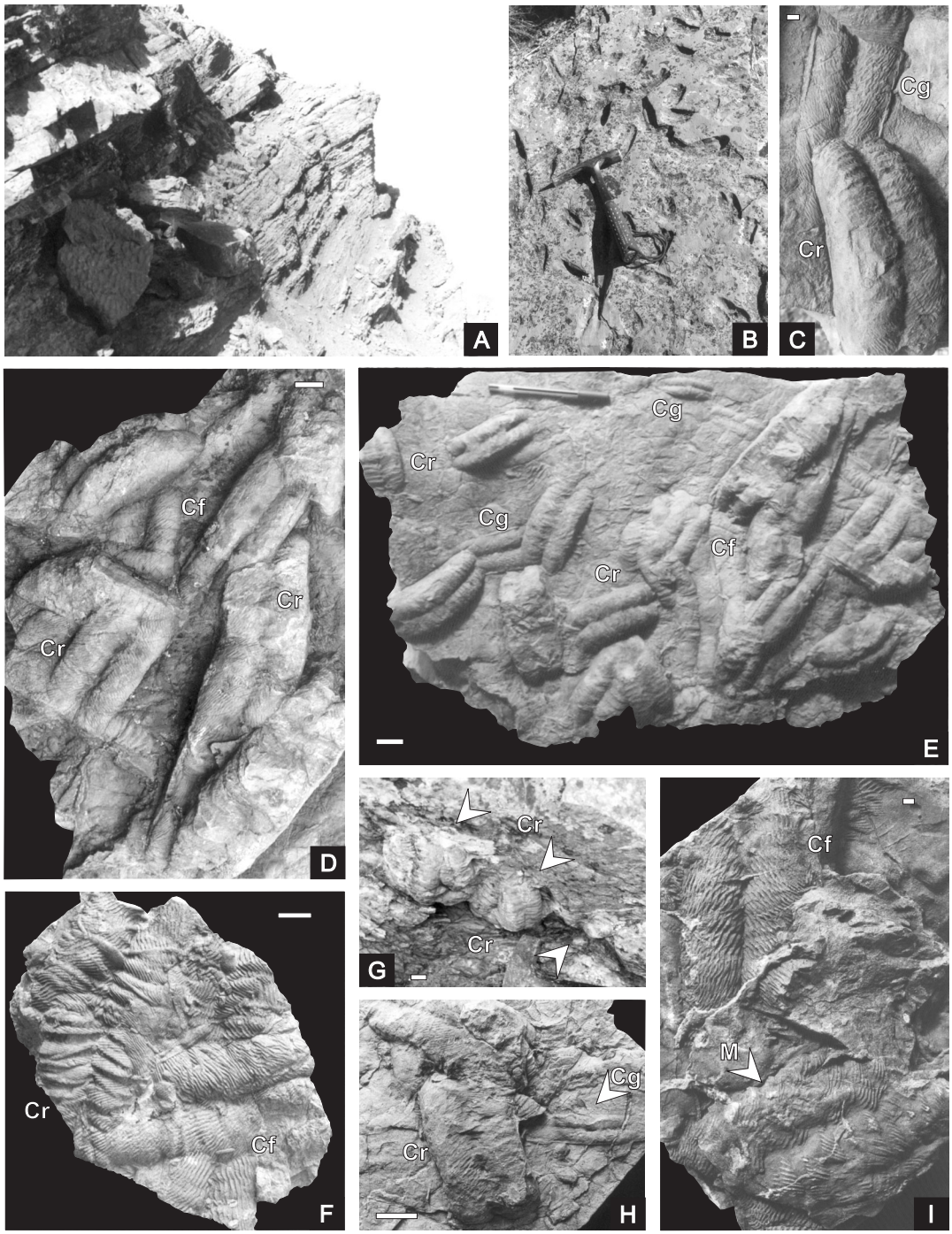

Figure 3. A, Outcrops with sandstone beds bearing the outstanding *Cruziana* pavements in Jujuy Province (NW Argentina). **B,** Infrequent preservation of *Cruziana* as negative epireliefs on the sandstone beds (hammer for scale, material in locus). **C,** Steeply walled *C. rugosa*, associated with *C. goldfussi* (scale 1 cm; MACN Icn 2253). **D,** Sandstone bed with an overcrossing association of *C. rugosa* and *C. furcifera* (scale 5 cm, material in locus). **E,** Large sandstone bed with several samples of the *C. rugosa* group (scale 5 cm; material exposed at the Museo "Bernardino Rivadavia" Buenos Aires; MACN Icn 2253). **F,** *C. rugosa* with well developed transverse corrugations along the trace and overimposed *C. furcifera* (scale 5 cm; PIL 15.100). **G,** In situ *Cruziana* on a sandstone sole of the locality (scale 5 cm; material in locus). **H,** partially preserved *C. rugosa* associated with a small sample of *C. goldfussi* (scale 5 cm; PIL 15.101). **I,** Clearly developed *C. furcifera* associated with *Monomorphichnus multilineatus* developed over a rare smooth sample of *C. rugosa* (scale 1 cm; material in locus)/***A,*** *Nuevos afloramientos con* Cruziana *en Jujuy (NO de Argentina).* ***B,*** *Preservación poco frecuente del icnogénero* Cruziana *como epirelieves negativos (foto de campo).* ***C,*** *Ejemplar profundo de* C. rugosa *asociado a* C. goldfussi *(escala 1 cm; MACN Icn 2253).* ***D,*** *Nivel arenoso con una asociación con entrecruzamientos de* C. rugosa *y* C. furcifera. *(escala 5 cm; material* in locus*).* ***E,*** *Base de arenisca con numerosos ejemplares asignados al grupo* rugosa *(escala 5 cm; material expuesto en el Museo Bernardino Rivadavia, Buenos Aires, MACN Icn 2253).* ***F,*** C. rugosa *asociada a* C. furcifera *mostrando típicas características de las icnoespecies (escala 5 cm; PIL 15.100).* ***G,*** *Base de arenisca con material de* Cruziana *in situ (escala 5 cm; material* in locus*).* ***H,*** C. rugosa *parcialmente preservada en asociación a* C. goldfussi *(escala 5 cm; PIL 15.101).* ***I,*** C. furcifera *vinculada a* Monomorphichnus multilineatus *desarrollado sobre un ejemplar superficialmente liso de* C. rugosa *(escala 1 cm; material* in locus*).*

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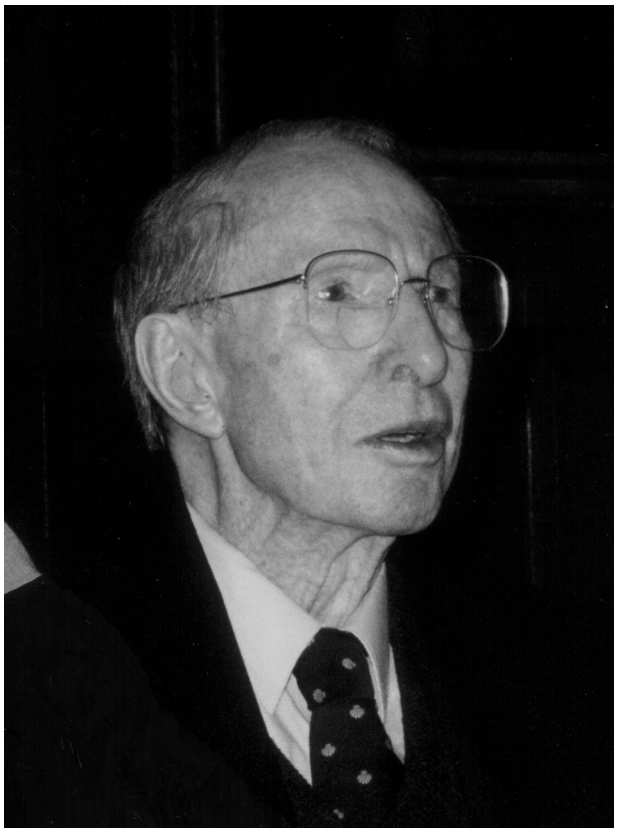
Tucumán 3087, Buenos Aires, Argentina

Nota necrológica

✞ Norman D. Newell (1909-2005)



El 18 de abril murió en su casa de Leonia, New Jersey, el eminente científico Normal Newell, terminando una larga y muy rica carrera académica como paleontólogo.

Nacido en Chicago el 27 de enero de 1909, e interesado en la paleontología desde su niñez, realizó sus estudios en la Universidad de Kansas mientras trabajaba en bandas de jazz para costeárselos, obteniendo su M.A a los 22 años y luego su doctorado en geología de la Universidad de Yale a los 25 años. Sus mentores fueron C.O. Dunbar y R.C. Moore.

Su especialidad fueron los bivalvos fósiles, y en este tema fue una reconocida autoridad mundial desde la publicación de su primera monografía sobre pectinoideos del Paleozoico superior (1937). Desde este conocimiento experto sobre un grupo biológico en particular, y sabiamente manteniendo siempre allí sus raíces, se expandió para abarcar una gran diversidad de temas. Una de sus contribuciones más perdurables fue su participación en la edición (y redacción de numerosos capítulos) de los volúmenes dedicados a los Bivalvia del *Treatise on Invertebrate Paleontology* (1969), que son la principal fuente de referencia sobre bivalvos fósiles aún hoy. Fue autor de numerosos artículos científicos y varios libros. Sus investigaciones y sus publicaciones han sido modelos para generaciones de paleontólogos, que encontraron en su impecable estilo la adecuada combinación de rigor más creatividad que muchos intentan y muy pocos logran.

Desde el comienzo de su vida académica demostró poseer un espíritu innovador y pionero en muy diversos campos de la geología y la paleontología. Fueron adelantados para su época, por ejemplo, (a) su acercamiento interdisciplinario al estudio de los fósiles, aplicando conceptos geológicos y zoológicos, y sentando las bases de la morfología funcional, como se evidencia desde sus monografías (1937 y 1942) sobre bivalvos del Paleozoico superior; (b) sus estudios de ambientes con depósitos carbonáticos actuales (plataforma de las Bahamas) y arrecifes coralinos (atolones de Raroia) con la finalidad de entender mejor los del pasado (arrecifes del Pérmico de Texas y de Túnez); (c) su llamado de atención sobre el hecho de que las extinciones masivas son fenómenos reales con gran influencia sobre la evolución de la vida, tema sobre el que publicó extensamente; y (d) su combate de lo que él llamada "analfabetismo científico" del público, que en su país ha condicionado durante años la educación y ha permitido el desarrollo de sectas anti-evolucionistas, contra las cuales su libro "*Creation and Evolution: Myth or Reality?*" (1982) sigue siendo la más lúcida exposición de argumentos, y por la cual la American Association for the Advancement of Science le otorgó el *Scientific Freedom and Responsibility Award*.

Norman Newell recibió otras importantes distinciones y premios de diversas instituciones, como reconocimiento a su polifacética y prolífica actividad: *Verrill Medal* del Peabody Museum, *The Paleontological Society Medal*, la primera *Raymond C. Moore Medal for Excellence in Paleontology* de la Society for Sedimentary Geology (1980), *Penrose Medal* de la Geological Society of America (1990), *Special Award* de la American Association of Petroleum Geologists (1996), y muy recientemente, el título de *Legendary Geoscientist* por el American Geological Institute (2004).

Enseñó en la Universidad de Wisconsin hasta 1945, pero luego su carrera estuvo ligada al American Museum of Natural History, donde fue curador, institución que, a su retiro, le otorgó la *Gold Medal for Achievement in Science* (1978) y lo nombró curador emérito. Al mismo tiempo, fue profesor de la Universidad de Columbia, donde creó un especial ambiente favorable para el desarrollo de la ciencia, como reconocen sus discípulos directos, entre quienes se cuentan, por ejemplo, R. Batten, D. Boyd, S.J. Gould, N. Eldredge y B. Kummel.

Fue además un científico comprometido con los problemas de su profesión y de la sociedad en general, y no regateó su tiempo ni sus esfuerzos para dirigir o formar parte de asociaciones y sociedades científicas, así fue Presidente de la Society for the Study of Evolution (1949), de The Paleontological Society (1960-1961), y del Consejo del Personal Científico del American Museum of Natural History (1966-1967).

Trabajó también extensamente en América del Sur: su estudio geológico sobre la región del Lago Titicaca (realizado entre 1942 y 1945 y publicado en 1949) sentó las bases de la estratigrafía y tectónica del área y es de obligada consulta para los geólogos interesados en el Altiplano peruano-boliviano. En 1947 dirigió una expedición para el estudio del Paleozoico Superior en Perú y sus resultados (Newell, Chronic y Roberts, 1953) establecieron la bioestratigrafía regional vigente hasta hoy.

Entusiasta trabajador hasta sus últimos días, Norman Newell nunca dejó de investigar y publicar sobre sus queridos bivalvos, especialmente en colaboración con su colega Don Boyd abarcando aspectos sistemáticos, evolutivos, paleoecológicos, tafonómicos. Estuvo presente y participó activamente en las últimas reuniones internacionales sobre biología y evolución de los bivalvos: en 1995 en el Tyrrell Museum, Alberta, Canadá, cuyo volumen de Proceedings se dedicó en su honor, y en 1999 en Cambridge, Gran Bretaña, donde se le rindió un emotivo homenaje y se tomó la fotografía que acompaña esta nota.

De temperamento formal pero abierto y accesible, con claras convicciones e intolerante de la mediocridad, Norman Newell contribuyó a cambiar la paleontología, y lo hizo sin estridencias ni grandes polémicas, simplemente con una sólida formación, rigor científico, creatividad y mucho trabajo.

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