sheet silicates, together with quartz in the case of the x-ray diffraction study of chaoite (*3*). It may appear surprising that a contaminant phase could have been misidentified as carbyne; however, it should be noted that in many of the reported electron diffraction studies (*1, 2, 9, 18*) crystalline carbyne grains appear to be a minor constituent of the whole sample. Also, up to 2.5 percent silicon by weight was found as an impurity in the carbyne sample described by Whittaker and Kintner (*5*). It is clear that in future searches for carbyne EDS analyses should be used to verify the chemistry of individual carbyne candidate grains.

Apart from diffraction observations, carbynes have been reported from negative-ion mass spectra obtained from an ion probe (*9, 19*). In this method the carbynes are recognized by their characteristic spectrum, in which the abundance of even-numbered carbon species is considered to reflect the tendency of a $-C{\equiv}C{-}C{\equiv}C-$ chain to cleave at the single bonds rather than at the triple bonds. Whittaker *et al.* (*9*) used reference spectra for graphite and the carbyne polymorphs to estimate the carbyne content of their sample; since the reference spectra have not been published it is difficult to comment on this work. However, the relative enrichment C_4^-/C_3^- of 2.1 to 3.0 reported by Herr *et al.* (*19*) and considered to be indicative of carbyne is close to the value of 2.0 obtained for amorphous carbon by the same technique (*20*) and less than the value of 4.1 reported for the thermal evaporation of graphite (*21*). Such enrichments of C_{2n}^- species in carbon vapors are in agreement with calculations of electron affinities based on molecular orbital theory (*22*) and can therefore be explained without the need for a carbyne phase. Pending the publication of further details concerning the reference spectra used in the identification of carbynes and the characterization of the reference standards (which must be based on electron diffraction and microanalysis), we consider that the negative-ion spectra do not provide compelling evidence for the existence of carbynes.

Doubts about the existence of carbynes have also been raised by Bundy (*23*), who questioned the reproducibility of Whittaker's phase equilibrium data (*6*), and by Jansta and Dousek (*24*), who questioned the thermodynamic stability of the proposed linear chain carbon structure. Another problem is the hexagonal, flakelike morphology reported for the carbynes (*25*), which suggests a sheet structure rather than the proposed structure of chains running parallel to the sixfold symmetry axis. In view of these concerns as well as the possibility of misidentifying sheet silicates as carbynes, we conclude that the evidence available at present is insufficient to establish the existence of the carbynes as new polymorphs of carbon.

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Geochronology of Type Uquian (Late Cenozoic) Land Mammal Age, Argentina

Abstract. *Mammal faunas collected from the Uquía Formation at Chucalezna and Esquina Blanca in Jujuy Province, northwest Argentina, are calibrated by potassium-argon age determinations and paleomagnetic polarity data. The sediments range in age from 2.5 million years old to perhaps as young as 1.5 million years, from late Pliocene through early Pleistocene, and correspond in time to late Blancan and early Irvingtonian land mammal age faunas in North America.*

In South America, as in North America, Cenozoic land mammal faunas from scattered localities are used by vertebrate paleontologists to subdivide geologic time. This practice has resulted in recognition of land mammal ages, which are based on aggregates of genera and species of fossil land mammals whose members are thought to have existed during a restricted interval of geologic time (*1*). A relative time scale for mammalian succession in South America is now agreed upon, and many beds and faunas have been partially calibrated by radioisotopic age determinations, magnetostratigraphic correlation with the magnetic polarity time scale, or both (*2, 3*). These geochronologic data are used to verify and refine the ages of the beds as inferred from composition and stage of evolution of the mammalian faunas.

Following establishment of the Panamanian land bridge about 3 million years ago, a reciprocal and apparently balanced interchange of the long-separated North and South American biotas occurred (*4*). The beginning of this interchange in South America is marked by the record of two mammalian genera (*5*) of North American origin in beds of Chapadmalalan (conventionally late Pliocene) age and about 20 mammalian genera (*5*) in beds of Uquian (conventionally early Pleistocene) age in Argentina (*6, 7*). Uquian faunas thus record the first major contingent of North American participants in the interchange.

We report radioisotopic age determinations and paleomagnetic data for faunas of Uquian age from the study of stratigraphic sections at Chucalezna and Esquina Blanca (about 4 km north of Chucalezna) in Jujuy Province, northwest Argentina (Fig. 1). Esquina Blanca, the most richly fossiliferous and stratigraphically the thickest section of known Uquian beds exposed in this area (*8*), is here designated the type locality for the Uquía Formation and the Uquian land mammal age, which were formally recognized by Kraglievich (*9*) when he spoke of the "Formación Uqueana" and "Fauna Uquiana," respectively.

Fossil mammals were discovered in the Uquía Formation by Enrique de Carles in 1912. Small collections of mammals from the beds at and near Esquina Blanca were assembled by early workers (*9, 10*), but their exact stratigraphic occurrence and associations are not known (*11*). Early workers were of the opinion that this fauna was transitional, partially filling the paleontological hiatus between the Chapadmalalan and Ensenadan (conventionally middle Pleistocene) land mammal age faunas (*9*). Study of the early collections (*9, 10*) revealed that the specimens came, more or less, from two different time intervals and horizons and that two different faunas were apparently represented. According to Kraglievich (*9, 10*), the older fauna, the Uquiense, is similar to typical Chapadmalalan faunas, and the younger is more similar to typical Ensenadan faunas. Simpson (*11*) cautioned that since faunas of more than one age appeared to be represented in the early collections from Uquía, a single fauna of an intermediate age was not demonstrated.

Castellanos (*8*), who collected additional specimens, noted the presence of a "*toba dacítica*" (dacite tuff) near the base of the beds. All his fossils came from above this tuff, and most were taken from within 30 m of it. He agreed with previous workers that the Uquía fauna represented a mixture of taxa "*araucanianos y pampeanos*" (that is, taxa of Pliocene and Pleistocene age, respectively).

Only four taxa belonging to groups of North American origin have so far been recorded from the Uquía Formation: three species of Tayassuidae (peccaries)—*Platygonus kraglievichi* (*12*), *P. uquiensis* (*12*), and ?*Mylohyus argentinus* (*12*)—and one species of Equidae (horses), *Hippidion uquiensis* (*9*). Castellanos (*8*) had recorded evidence of only two of these taxa—*Platygonus* sp. from about 27 m above the base of his profile 5, and ?*M. argentinus* from about 11.5 m above the tuff in his profile 8.

The best examples of Uquian fauna occur in the Barranca de Los Lobos, Vorohué, and San Andrés formations superjacent to the Chapadmalal Formation along coastal Buenos Aires Province (*13*). Fossil mammals from these beds fill, in part, the paleontological hiatus between typical Chapadmalalan and Ensenadan faunas (*14*), and our concept of an Uquian land mammal age fauna is based primarily on knowledge of fossils from these beds (*15*). The fossiliferous sediments, however, are not suited to paleomagnetic studies, and there are no intercalated volcanic rocks for radioisotopic dating.

Table 1. Analytical data for radioisotopic (^{40}K-^{40}Ar) age determinations. Calculations are based on radioactive decay constants $^{40}K\lambda_{\beta} = 4.962 \times 10^{-10}$ year^{-1} and $\lambda^{40}K^{e} + \lambda'^{40}K^{e} = 0.581 \times 10^{-10}$ year^{-1} and on the isotopic abundance $^{40}K = 0.01167$ percent of total K. For sample locations see text and Figs. 1 and 2.

Sample				Potassium (%)	Radiogenic ^{40}Ar ($\times 10^{-11}$) (mole/g)	Atmospheric ^{40}Ar (%)	Age ($\times 10^6$ years)
Collector number	Lab number	Material dated	Weight (g)				
LGM 205*	KA 3835	Glass	4.8900	3.944 ± 0.015	2.25	81	3.29 ± 0.10
LGM 205*	KA 3835R	Glass	4.3361	3.944 ± 0.015	1.95	29	2.86 ± 0.08
LGM 205*	KA 3835R2	Glass	4.0475	3.944 ± 0.015	2.33	33	3.40 ± 0.04
LGM 205*	KA 3836	Biotite	0.8494	6.794 ± 0.002	3.30	82	2.78 ± 0.09
LGM 201†	KA 3863	Glass	2.5490	3.078 ± 0.03	3.32	90	3.7 ± 0.5
LGM 201†	KA 3865	Glass	2.2482	3.384 ± 0.03	3.32	61	3.8 ± 0.2
LGM 202A‡	KA 3912	Glass	2.7645	3.958 ± 0.04	2.43	36	3.54 ± 0.04
LGM 204§	KA 3938	Biotite	2.4352	7.626 ± 0.24	3.29	31	5.3 ± 0.2

*Lowest dacite tuff in Chucalezna section; samples handpicked under binocular scope to remove obvious contaminating grains. †Upper reworked vitric tuff in Esquina Blanca section. ‡Lowest dacite tuff in Esquina Blanca section. §Upper (third) tuff from Chucalezna section (=LGM 201 from Esquina Blanca section).

The Uquía Formation at and between Chucalezna and Esquina Blanca consist of gently folded fluvial sediments ranging from clays to pebble conglomerates. Exposed near the base sections at each locality is a prominent white dacitic tuff unit, the *toba dacítica* of Castellanos (*8*), which reaches a maximum thickness of 2 m and completely pinches out in some places, indicating deposition on an irregular surface. Where thickest, the tuff has finely laminated beds; occasional cross-bedding indicates fluviatile deposition. The lower beds contain coarse glass shards and anhedral volcanic biotite mixed with pockets of finer sandy detrital minerals derived from Mesozoic age strata exposed in mountain ranges to the west.

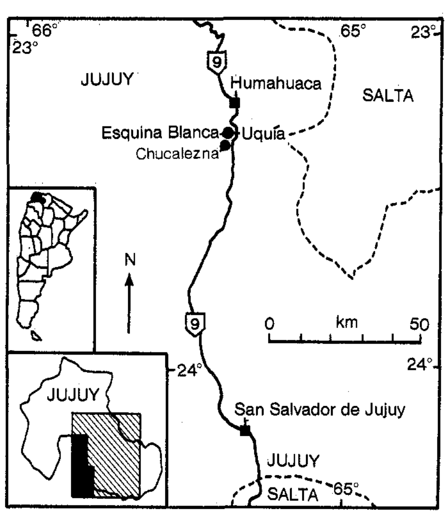

Fig. 1. Map of portion of Jujuy Province, northwest Argentina, showing Chucalezna and Esquina Blanca localities.

Sample LGM 205 is basal dacitic tuff from the Chucalezna section, and sample LGM 202 is from the Esquina Blanca section (Fig. 2). The grains of biotite and glass in these samples are larger than those of the contaminating sand, permitting separation of nearly pure concentrates for ^{40}K-^{40}Ar dating. Although samples from the uppermost tuff in each section (LGM 204, Chucalezna; and LGM 201, Esquina Blanca) appeared to contain pure biotite and glass separates, the inherent grain size of the volcanic glass and biotite more nearly matched the detrital grain size of the tuffaceous sand matrix; the contaminating material could not be completely removed, and anomalously old ages were obtained relative to the basal dacitic tuff.

Two ^{40}K-^{40}Ar dates from sample LGM 205 from the Chucalezna section appear to be reliable estimates of the age of this tuff (Table 1): KA 3835R, a coarse glass (> 60 mesh), and KA 3836, a coarse biotite, gave such nearly concordant ages that it seems unlikely that significant amounts of different contaminants would uniformly affect both dates. We conclude that the base of the Chucalezna section and, by correlation, the base of the Esquina Blanca section is younger than 2.8 million years.

Paleomagnetic analysis of block samples (*16*) from 20 sites in a 215-m section of the Uquía Formation at Esquina Blanca (Fig. 2) revealed that the section is almost entirely of reversed polarity (*17*). The basal site shows normal polarity, but the site immediately overlying it is transitional, containing two reversed polarity

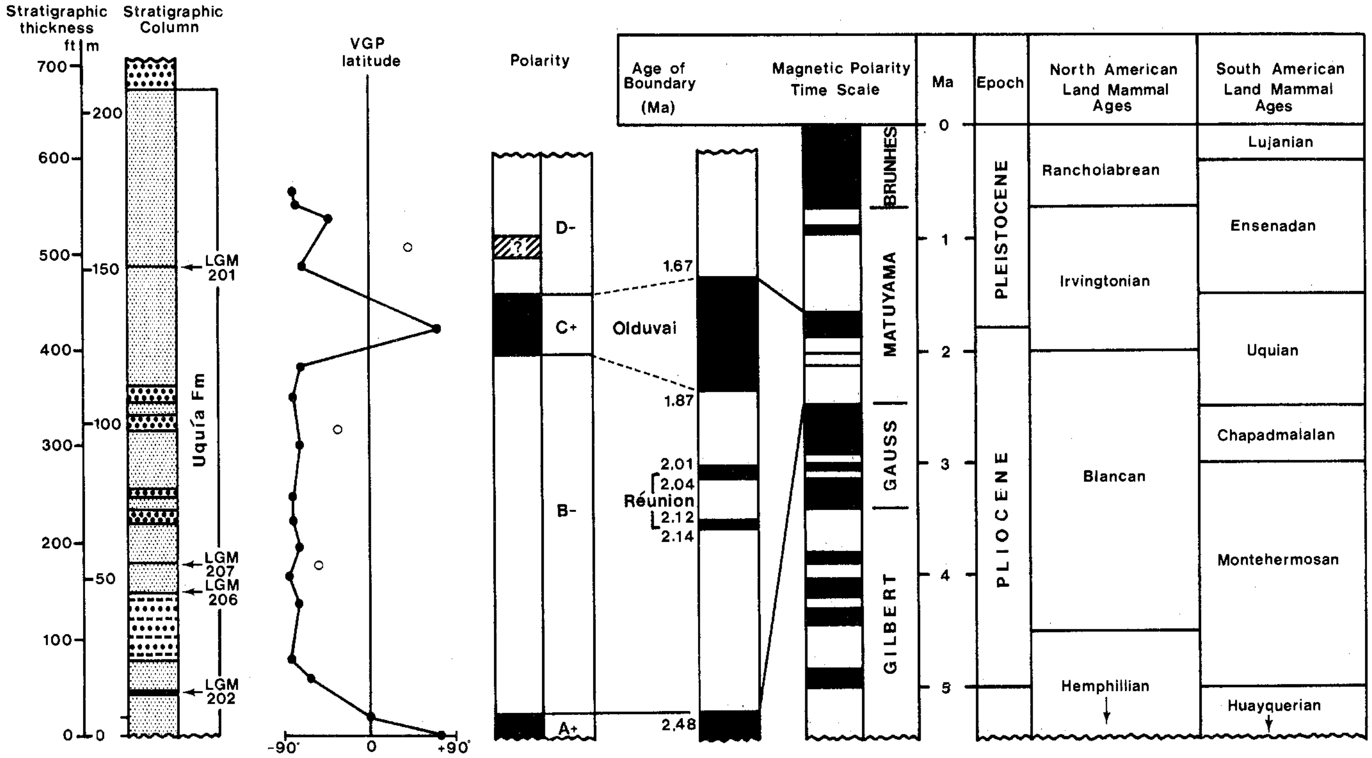

Fig. 2. Lithostratigraphy and magnetostratigraphy for section at Esquina Blanca, Jujuy Province, northwest Argentina. In the stratigraphic column, the small dot pattern indicates sandstone, the dot-dash pattern siltstone, the large dot pattern conglomerate, and the bold solid lines tuffs. Mean virtual geomagnetic pole (VGP) latitude after alternating field demagnetization is shown for sites at which clustering of natural remanent magnetization vectors are significant from selection from a random population at the 95 percent confidence level (●) and for sites with poorer clustering (○). Positive VGP latitudes indicate normal polarity and are shown by black bars; negative VGP latitudes are reversed polarity and are shown by white bars (*21*). The magnetic polarity time scale follows Mankinen and Dalrymple (*22*); the geologic time scale follows Berggren and Van Couvering (*23*); and chronology of North American land mammal ages follows that described in (*4*). The approximate correlations of North and South American land mammal ages are based on data presented in this report and in (*3*). *Ma*, million years.

samples and one normal polarity sample. A site of definite normal polarity occurs at 135 m. We do not consider the site at 160 m to be a reliable indicator of normal polarity. One sample from the site showed clear reversed polarity, but two others moved toward but failed to reach the expected reversed polarity direction. Although the final mean virtual geomagnetic pole latitude is positive, the natural remanent magnetization vectors are not well clustered. This site probably contains a significant normal polarity overprint which could not be completely erased. The resulting polarity interpretation (Fig. 2) is judged to be the most probable correlation to the magnetic polarity time scale and is based on the following evidence.

1) The virtually synchronous appearance of seven genera belonging to groups of South American origin in North America in rocks of late Blancan age, dated around 2.5 million years old (*18*), documents the existence of the Panamanian land bridge by that time and marks the beginning of the interchange between continents (*3*). If the first appearance of participants in the interchange in North and South America indicates temporal synchronization, then there is reason to infer equivalence of late Blancan with Chapadmalalan and early Uquian. Chapadmalalan and early Uquian beds and faunas would then predictably be between 3.0 and 2.0 million years old.

2) The average radioisotopic age of 2.8 million years for nearly concordant biotite and glass dates of the *toba dacítica* approximates the true age of the tuff and provides a maximum age for the base of the paleomagnetic section.

3) Given the age constraints provided by content of the fauna and the proposed maximum age for the tuff at the base of the section, then the polarity zone designated Uquía A+ (Fig. 2) correlates with the upper portion of the Gauss normal polarity chron, and the overlying reversed polarity zone Uquía B− correlates with the older portion of the Matuyama reversed polarity chron. No other correlation is possible without violating the biostratigraphic and radioisotopic data. Correlation of normal polarity zone Uquía C+ with the Olduvai event represents the most likely correlation of that polarity zone to the magnetic polarity time scale.

In summary, the Uquía Formation ranges from 2.5 to about 1.5 million years in age, and the lowest level yielding fossil land mammals ranges from about 2.5 to 2.4 million years in age. These data permit refinement of estimates of durations and boundaries of late Cenozoic land mammal age faunas in South America and estimates of correlations of these faunas with North American land mammal age faunas (Fig. 2).

In view of the 2.5 million year age of the base of the Uquía Formation and of the 3.5 million year age of Montehermosan beds at Corral Quemado (*3*), the validity of an intermediate Chapadmalalan age needs careful reevaluation. Refinement of the ages of some Montehermosan, Chapadmalalan, and early Uquian beds and faunas as currently recognized (*6, 19*) may show them to be synchronous in age or nearly so.

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17. Natural remanent magnetization (NRM) was measured by R.F.B. on a cryogenic magnetometer at the U.S. Geological Survey, Menlo Park; alternating-field (AF) demagnetization was done with a single-axis demagnetizer. Intensities of NRM ranged from 8×10^{-7} to 4×10^{-4} gauss. Progressive demagnetization studies indicated that, in most cases, secondary components of NRM were erased by AF demagnetization at 200-Oe peak field. The remaining characteristic NRM is believed to be a depositional remanent magnetization. Isothermal remanent magnetization characteristics and Curie temperature determinations on magnetic separates indicate that the carrier of the remanence is detrital magnetite, which may have suffered a small degree of low-temperature oxidation to maghemite. After initial measurement of NRM, all samples were demagnetized at 200-Oe peak field and measured again. Site average directions were calculated by the technique of R. A. Fisher [*Proc. R. Soc. London Ser. A* **217**, 295 (1953)], and the site average directions were used to compute the virtual geomagnetic pole latitudes (Fig. 2). Any site yielding ambiguous polarity determination after AF demagnetization to 200-Oe peak field was subjected to further demagnetization at 100-Oe steps up to 500 Oe in order to clarify the polarity of the characteristic NRM. Clustering of the NRM vectors after alternating field demagnetization was tested by the statistical technique of G. S. Watson [*Mon. Not. R. Astron. Soc. Geophys. Suppl.* **1**, 160 (1956)] to determine whether the grouping was significant from selection from a random population at a 95 percent confidence level. Sites which yield NRM vectors that pass this test are judged more reliable than sites from which the NRM vectors show poorer grouping.
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21. Polarity zones in Fig. 2 are designated by the prefix "Uquía" after the nearby geographic location Uquía. The basal normal polarity zone is thus designated Uquía A+. This nomenclature is in keeping with recommendations regarding magnetostratigraphic nomenclature described in *Geology* **7**, 578 (1979). Time intervals of the magnetic polarity time scale are referred to by attaching the suffix chron.
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Catastrophic Decline of a Top Carnivore in the Gulf of California Rocky Intertidal Zone

Abstract. *The predatory sun star,* Heliaster kubiniji, *once the commonest rocky intertidal asteroid of the Gulf of California, has been rare throughout this region since summer 1978 when a devastating disease outbreak occurred. This unprecedented phenomenon and several other exceptional ecological events in marine communities of the northeastern Pacific appear to be linked to large-scale climatic changes that occurred during 1977 and 1978. Implications of the decline in* Heliaster kubiniji *are discussed.*

Extreme population fluctuations are likely to be important in the evolutionary history of a population (*1*). They may also have secondary effects on co-occurring species, a dramatic case in point being the recent crown-of-thorns starfish population explosion (*2*). We report here on a phenomenon of the opposite kind, the population crash of the predatory sun star, *Heliaster kubiniji* Xantus, throughout its principal range in the Gulf of California. The crash appears to be one of a series of events that were triggered by climate changes in the northeastern Pacific.

Prior to the summer of 1978, this large (up to 220 mm in diameter) multirayed asteroid was conspicuous in rocky intertidal habitats throughout the Gulf of California. In 1941, Steinbeck and Ricketts (*3*) characterized *H. kubiniji* as "the most common, obvious, and widely distributed shore starfish in the Gulf." At Puerto Peñasco, Sonora, Mexico, *H. kubiniji* was found regularly in abundance from 1946 to 1978 (*4*). This species was collected extensively in the northern Gulf by Paine in 1962–1964 (*5*), and found to be the commonest asteroid of rocky intertidal habitats of the Gulf in surveys during 1974–1975 (*6*). Brusca (*7*) also considered *Heliaster kubiniji* to be the commonest rocky-shore asteroid in the Gulf, found in greatest numbers in the northern and central Gulf, and ranging to Central America. This species occurred widely at densities of 0.1 to 1.0 per square meter in the northern and central Gulf prior to July 1978 (*6*, *8*).

Scores of disintegrating sun stars were first observed during 18 to 20 June 1978 in the intertidal zone around Puerto Peñasco. Animals initially exhibited whitish lesions on the aboral surface. The lesions rapidly enlarged until the entire animal fragmented, and the decaying parts of the same individual were left in close proximity. High concentrations of bacteria were found in the lesions (*9*), but it is not known whether bacterial infection was the primary cause of death. Mortality of *H. kubiniji* approached 100 percent; within 2 weeks the sun star had virtually disappeared from this site.

Since the initial die-off was observed at Puerto Peñasco, we have surveyed many sites in the northern and central Gulf, and solicited information from colleagues who were familiar with *H. kubiniji* and who had worked in the Gulf in recent years in attempts to determine the present and former (pre-1978) status of the sun star. The decline of *H. kubiniji*, which to the best of our knowledge occurred throughout the Gulf during summer 1978, has been precipitous. Figure 1 shows the approximate locations of sites where *H. kibiniji* (i) was abundant and could be found at densities within the above range prior to 1978 and (ii) has either not been found at all, or at maximum local densities less than 0.05 per square meter in one or more surveys since summer 1978 (*10*). In more than 3 years, with several sites being monitored regularly, neither we nor our colleagues have found a single site where *H. kubiniji* has persisted at high densities, or where substantial recruitment of juveniles has occurred. Samples span the region

0036-8075/82/0528-0989$01.00/0