

side to the fault to the northeast, an azimuth not sensitive to differences in directivity along the fault trace. However, the high-frequency portions of the spectra are dominant in opposite directions along the fault for the two events, indicating that the 5 June foreshock ruptured to the southeast while the later foreshock ruptured northwestward. The spectral differences illustrated in Fig. 2D are typical of the subtle but clear seismological evidence for differences in directivity of Parkfield earthquakes.

The similarities in fault behavior in the 1934 and 1966 sequences suggest a scenario for Parkfield earthquakes. An M_L 5.0 earthquake (the foreshock) occurs immediately northwest of the bend in the fault (the 5° change in the strike of the fault trace), which acts as a barrier to slip. The fault zone near the hypocenter of the main shock, southeast of the bend, is loaded by slip associated with the foreshock, even though that slip need not extend through the bend to the vicinity of the main shock hypocenter. The main shock does not occur immediately, but the loading is sufficient to initiate the inevitable failure of the fault zone southeast of the bend. The main shock occurs about 17 minutes later immediately southeast of the bend, which again acts as a barrier to slip, directing rupture growth toward the southeast. Note that breaking of the bend itself during the sequence is not necessary even though the loading stress is transmitted across it. The extent of rupture during the main shock may be controlled by physical discontinuities on the fault surface (6, 15). Great earthquakes on the San Andreas fault, such as that in 1857, would thus initially resemble moderate-sized events and grow to full extent by breaking the barriers that arrest slip in the M_L 5½ shocks. It may well be, then, that successful prediction of major earthquakes (that is, smaller ruptures that have "gotten away") will involve an assessment of the potential for rupture growth across barriers.

Although the initial stages of the 1934 and 1966 Parkfield sequences were similar, the 1934 sequence included an early M_L 5.0 foreshock (the reference event in Fig. 2D), whereas the 1966 sequence did not (4, 9). Improved instrumental coverage in 1966 revealed southeastward migration of small earthquakes in the months preceding the main shock toward its epicenter (9), while fresh cracks on the fault southeast of Parkfield 2 weeks before the 1966 main shock (16) are consistent with substantial precursory aseismic slip on the fault. The migration of small shocks or precursory aseismic slip,

or both, could serve as the 1966 loading counterpart to the early 1934 foreshock. The sparse instrumental data available for the 1922 Parkfield earthquake and the similar descriptions for the 1901 Parkfield shock strongly suggest that they occurred near and were comparable in size to the 1934 and 1966 main shocks; neither was preceded by felt foreshocks (17), so that the 1901 and 1922 Parkfield shocks do not conform precisely to the proposed scenario. However, the failure patterns in 1934 and 1966 suggest that future M_L 5½ earthquakes at Parkfield will follow episodes of stress concentration at the bend in the fault trace.

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19. A cosine taper was applied to the final 5 percent (0.15 second) of the first seismic phase before computing the Fourier spectrum.
20. We thank A. Lindh and W. Stuart for suggestions and B. Raleigh and R. Archuleta for critical reading of the manuscript.

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Dinosaurs: A Jurassic Assemblage from Patagonia

Abstract. *The first Jurassic assemblage of carnosaurs and sauropods from South America has been recorded in the Callovian-Oxfordian beds of Patagonia. The new genus of carnosaur is related to Allosaurus. The two new genera of sauropods are cetiosaurids, comparable with but different from Cetiosaurus, and more primitive than Haplocanthosaurus.*

An important fossil locality with a Jurassic assemblage of dinosaurs has been discovered in the Argentine Patagonia. The new evidence consists of relatively well-preserved specimens of two genera of Sauropoda and of one genus of Carno-

sauria. The age of the fossiliferous beds is Callovian-Oxfordian (1), some 15 million years older than the well-known dinosaur faunas from the Morrison formation and the Tendaguru beds, both assigned to or considered the top of the Jurassic.

As would be expected, the anatomical characteristics of the species recently discovered in Patagonia are more primitive than those of comparable species of the cited dinosaur faunas. Knowledge of the Jurassic assemblages of dinosaurs is largely based on the rich information from the end of that period (Morrison and Tendaguru); only relatively poor information is available for the rest of the

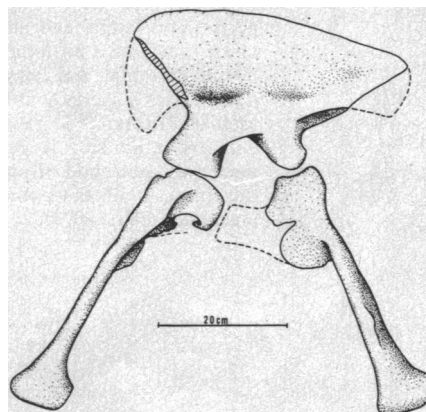


Fig. 1. Lateral view of the pelvis of *Piatnitzkysaurus floresi* n.g.n.sp. (new genus, new species), a megalosaurid carnosaur from the Jurassic of Patagonia (specimen PVL. 4073).

Jurassic (a time span of about 55 million years).

Little is known of the evolutionary history, geographical distribution, and composition of the dinosaur faunas before the Morrison and Tendaguru times. However, some evidence from Middle Jurassic sites in England, North Africa, and South America, and from Lower Jurassic sites of Europe, Australia, India, and the United States provides basic knowledge, although neither detailed nor extensive. Hence, the new discoveries in Patagonia reveal the existence of an important assemblage of carnosaur and sauropod dinosaurs, represented by well-preserved specimens that suggest some details of their evolution before the end of the Jurassic. This dinosaur assemblage from the Callovian-

Oxfordian may be the only one available that affords an evolutionary picture of the saurischians before the Morrison and Tendaguru times.

The carnosaur is represented by most of the associated bones of a single individual, but lacking evidence of the foot and hand. This specimen corresponds to a new genus and species of the family Megalosauridae, *Piatnitzkysaurus floresi* (Fig. 1), related to *Allosaurus* (2) from the Upper Jurassic in the United States, but with more primitive features in the pelvis, that is, the smaller "foot" of the pubis and the obturator foramen almost completely bordered by bone. The morphology of the vertebrae is similar to that of *Allosaurus*, except for some differences in the system of ridges on the lateral side of the neural arches of the

dorsals. Supposedly, the humerus of the Patagonian carnosaur is proportionally longer than in *Allosaurus*. The affinities with *Ceratosaurus* (3) appear less evident than with *Allosaurus*.

The sauropods are represented by two new genera and species of the family Cetiosauridae. One of them, *Patagosaurus fariasi* (Fig. 2), is based on an almost complete postcranial skeleton of the size of *Cetiosaurus leedsi* and shows similarities to it. The morphology of the cervical vertebrae with nonbifurcated neural spines, the characteristics of the shallow pleurocoels of the dorsals, and the basic features of the ilium and ischium are similar to the English genus *Cetiosaurus*. However, clear differences are evident in the morphology of the neural spines of the caudal vertebrae and in the distal part of the ischium, which appear of generic value.

According to the vertebrae morphology, *Patagosaurus fariasi* appears to be more advanced than the Bathonian genus *Amygdalodon* (4). It is comparable to *Cetiosaurus* but more primitive than *Haplocanthosaurus* from the Morrison beds, the latter with more pronounced pleurocoels and a larger height of the neural arches below the transverse processes of the dorsal vertebrae.

The remaining new genus and species of sauropod found in Patagonia is *Volkheimeria chubutensis* (Fig. 3), as judged by an incomplete postcranial skeleton with distinct diagnostic features. The ischium of this specimen is primitive, of the *Cetiosaurus* type, but with a distal thickening as in *Patagosaurus*. The ilium is shorter and higher than in *Patagosaurus*, and the pubis shows the proximal region shorter anterior-posteriorly. The ratio of the tibia length to the femur is 1:1.7. The available dorsal vertebrae differ from those of *Patagosaurus* and *Haplocanthosaurus* in that the neural spines are laterally compressed and the neural arches are very low. Thus, *Volkheimeria* suggests a more primitive stage than that characterized by the cited sauropods.

This record is the first indication that South America was populated during Callovian-Oxfordian times by carnosaurs and sauropods assemblages. Paleogeographically, the new evidence supports the idea that during the Jurassic a terrestrial fauna interchange was possible between South America and other continents (for example, Africa and North America).

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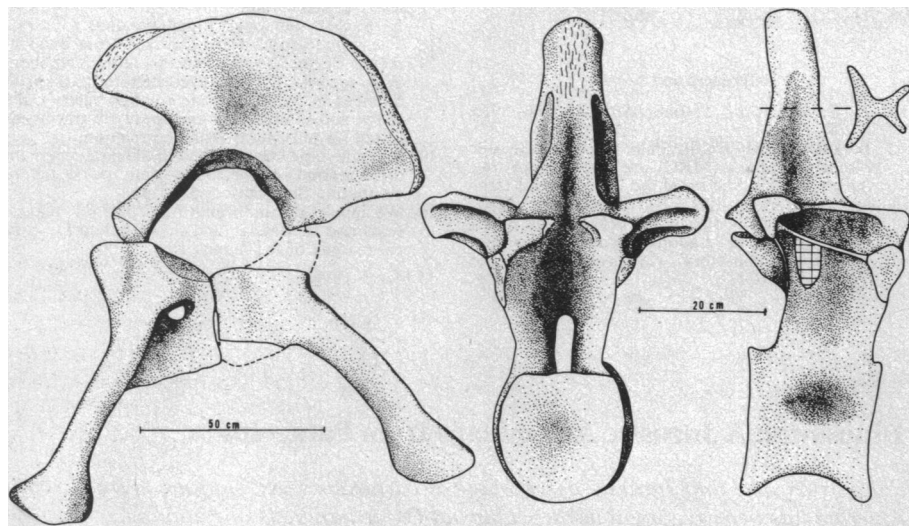


Fig. 2. Lateral view of the pelvis (inverted) and anterior and lateral view of a posterior dorsal vertebra of *Patagosaurus fariasi* n.g.n.sp., a cetiosaurid sauropod from the Jurassic of Patagonia (specimen PVL. 4170).

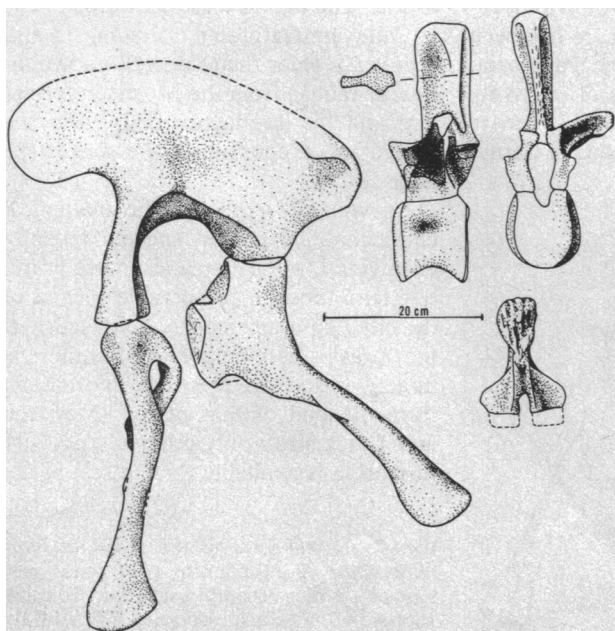


Fig. 3. Lateral view of the pelvis, and lateral and anterior views of a posterior dorsal vertebra, and anterior view of a sacral neural arch of *Volkheimeria chubutensis* n.g.n.sp., a cetiosaurid sauropod from the Jurassic of Patagonia (specimen PVL. 4077).

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Morphine-Naloxone Interactions: A Role for Nonspecific Morphine Excitatory Effects in Withdrawal

Abstract. *The opiate antagonist naloxone precipitates withdrawal when given either 15 minutes after or 1 minute before a single injection of morphine in drug-naïve mice. We propose that withdrawal signs arise from a synergistic mixture of excitatory influences that are direct (agonistic action on nonspecific opiate receptors) and indirect (sensory and affective disorders, stress, hormonal and neurotransmitter dysfunction, and so forth). The predominant effects during precipitated withdrawal are assumed to be direct, whereas during abstinence in tolerant animals they are indirect.*

As much as 50 years ago, morphine was reported to be "at one and the same time a depressant and a stimulant" (1), with stimulation unexplainably evident after administration of single massive doses or after prolonged administration in which large doses are reached gradually. In recent years the excitatory nature of morphine has been documented in terms of acetylcholine turnover (2) and of increased impulse discharge of certain neurons, both after single doses (3) and during repeated administration (4). We have also been unable to explain convincingly the fact that during repeated administration, tolerance develops for the depressant action while hypersensitivity can develop to the excitatory action (5).

We report here data that we believe can permit these perplexing questions to be answered. The rationale for these experiments was developed in consequence of recent reports about morphine excitatory effects. Jacquet and colleagues demonstrated that morphine microinjection into the periaqueductal gray of drug-naïve rats could cause excitation in addition to the commonly seen catalepsy and analgesia; the excitation was not reversed by naloxone, a stereospecific antagonist (6). Such excitatory effects were mimicked by microinjection of *d*-morphine, which does not act stereospecifically at the opiate receptor (7). This excitatory response to morphine was similar to the behaviors seen in the withdrawal syndrome; it was suggested that precipitated abstinence could be due to a selective blockade of stereospecific receptors but not of nonspecific receptors (that is, receptors that are not blocked by naloxone).

This hypothesis is partially supported

by the demonstration that naloxone, a drug generally presumed to cause a stereospecific blockade of opiate receptors, could precipitate withdrawal after only a single dose of morphine (8). However, withdrawal could not be demonstrated after morphine injection into an animal that had been first treated with naloxone (9). This was interpreted to mean that the nonspecific excitatory effects were not causing withdrawal.

Nonetheless, we believed that the previous failures to demonstrate a morphine role in withdrawal reactions were correctable by changes in experimental procedures. In our preliminary tests, several factors appeared to be critical:

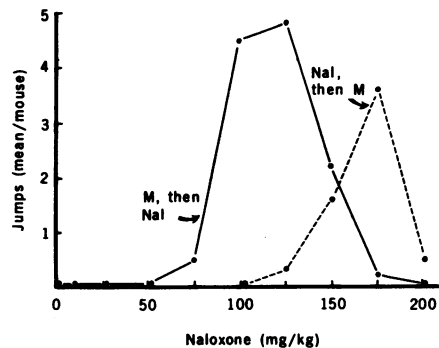


Fig. 1. Opiate-withdrawal jumping when naloxone is given either 1 minute before or 15 minutes after a single dose of morphine (50 mg/kg) in previously unexposed mice. The greater effectiveness of naloxone (Nal) when it is given after morphine (M) could indicate some rapid-onset tolerance within 15 minutes after morphine or could reflect the locomotor inhibitory effect of naloxone when it is given alone (before) morphine. Six mice were tested per data point; these same doses of naloxone given to saline-treated mice never produced jumping. Numbers of mice showing jumping at the optimal doses for both naloxone curves differed significantly from saline-injected controls ($P < .05$, chi-square test).

the ratio of morphine to naloxone dosage, the requirement for a large dose of naloxone, and the need to reduce the time interval between injections when naloxone was given first.

Subjects were female Texas-Swiss outbred mice, injected intraperitoneally with morphine and naloxone in various sequences and doses. Pilot studies indicated that a convenient morphine dose for this purpose was 50 mg per kilogram of body weight. Mice were housed communally with a constant number of mice per cage. All treatments were given between 1800 and 2200 hours. Behavioral signs of withdrawal that were evaluated are the commonly accepted signs of hyperactivity, hyperreactivity, repeated escape attempts, rearing and sniffing, and piloerection. However, the most objective and quantifiable sign, stereotypic jumping, was the prime index of precipitated withdrawal. Number of jumps for each mouse was scored during the first 15 minutes after the last drug injection; a jump was scored whenever a mouse cleared the wall of an opaque plastic dishpan 34 by 30 by 14 cm.

Initially, we evaluated precipitated withdrawal when morphine was administered first, followed in 15 minutes by naloxone in a full range of doses (left curve in Fig. 1). Naloxone reliably precipitated withdrawal symptoms at doses between 125 and 175 mg/kg. These doses are higher than those used by Jacob *et al.* (9, 10). The inhibition of withdrawal by still higher doses of naloxone is presumed to reflect the importance of the agonist-antagonist ratio. For a given dose of morphine, only a certain range of naloxone was effective; this may also indicate other behavioral effects of naloxone.

Rapid development of tolerance to single doses of morphine occurs under certain conditions. To see if such a phenomenon could underlie our precipitated abstinence, we concluded a second series of tests in which naloxone was given first, followed 1 minute later by morphine. Using a similar dose range as before, we found that withdrawal signs were produced even under these conditions (right curve in Fig. 1). Lower doses of naloxone also precipitated withdrawal symptoms, but jumping occurred with less reliability. Jumping never occurred in saline-injected controls ($N = 6$ for each dose of naloxone).

High doses (> 25 mg/kg) of naloxone, given alone, caused apparent freeze behavior, with pronounced huddling in one corner of the cage and conspicuous lack of exploratory behavior. Such behaviors interfere with induction of jumping, but