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Two new fossil vertebrate localities in the Santa Cruz Formation (late early – early middle Miocene, Argentina), ~51° South latitude

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Abstract

Two new fossil vertebrate localities are described from the Santa Cruz Formation (late early – early middle Miocene) of coastal Patagonia. They are noteworthy because they are the lowest stratigraphically of any precisely recorded in coastal Santa Cruz Province and they contain a rich fauna including many partially articulated skeletons undisturbed by collecting. Thus, they offer the potential for taphonomic analysis and paleocommunity reconstruction. The latter is particularly intriguing because the fauna document the Miocene Climatic Optimum at >51° South latitude. Together with several previously documented sites in this region, it offers a potential window into the nature of mammalian communities farther south than any other in the world during this time and documents the farthest south distribution of primates.

Keywords: Miocene; Santa Cruz Formation; Paleontology; Argentina

1. Introduction

Coastal exposures of the Santa Cruz Formation between Río Coyle and Río Gallegos have been a fertile ground for recovery of late early–early middle Miocene fossil mammals for more than 100 years. Fossils from this general area have been collected by Ameghino, Hatcher, Riggs, Martin, and Tauber, among others (Hatcher, 1903; Marshall, 1976; Tauber, 1994, 1997; Torcelli, 1918). The outcrops are remarkable for the completeness of the fossils they yield, including skulls with associated skeletons, which allows for a more complete assessment of the phylogeny of the taxa represented and a better reconstruction of their adaptive profiles than is generally the case when fossil material is fragmentary and disassociated. Such fragmentary material, mostly jaws and teeth, makes up much of the fossil record from Santa Cruz Formation localities, about 60–90 km farther north, such as at Monte Observación and Monte León (Bown and Fleagle, 1993).

Fossil levels in the previously mentioned region are located in the Atlantic intertidal zone, seaward from the base of a cliff 50 or more meters high. The maximum tidal amplitude is 12.8 m, the third greatest in the world. The exposures can be reached from the low, featureless Patagonian plateau via small canyons leading to the sea. Previously known coastal fossil localities summarized by Marshall (1976) and more recently by Tauber (Tauber, 1994, 1996, 1997) are very close to these access points. Venturing further from the known localities and beach access points, we have discovered two new localities rich in fossil

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specimens and notable in their species diversity (richness). One of these new localities is stratigraphically equivalent to the lowest fossil levels reported hitherto (Tauber, 1994, 1997). The other is more than 20 m lower stratigraphically than any reported previously. We provide a preliminary description of the localities and a stratigraphic summary of the cliff and beach exposures covering the 13 km uninterrupted stretch reaching from Cañadón del Indio at Coyle Inlet in the north to a major slump 3 km north of Estancia La Costa, the most northerly fossil locality previously recorded. We give a preliminary list of the materials recovered in the field season of 2006. The two localities are hereby named Anfiteatro and Campo Barranca.

2. Previously known localities

Atlantic coastal localities along the 70 km stretch from the inlet of Río Gallegos northward to Coyle Inlet are summarized in Fig. 1. From south to north, there are several previously reported localities. On the basis of an estimated 3° average southeastward regional attitude of the Santa Cruz Formation, Tauber (1994, 1996) interprets these localities as stratigraphically superimposed, such that the most southerly beach-level localities are geologically youngest. The presumed youngest and most southerly locality, Cabo Buen Tiempo is not particularly fossiliferous. Continuing northward, Monte Tigre and Cañadón las Totoras (= Ea. La Angelina of Marshall 1976) are very fossiliferous. These localities may be regarded as a suite: Tauber (1994) notes they are lithologically similar and associated with higher-energy deposition (more gravel and sand, less silt and clay) than localities in the lower parts of the formation, mentioned subsequently. Also, they lack the tuffacious horizons notable farther northward. Finally, they apparently contain some faunal elements but lack several others that are found in three presumably older and more northerly localities.

A second suite of localities is associated with tuff horizons; contains more claystones, siltstones, and fine-grained sandstones with some small gravel lenses; and is faunally distinct (Tauber, 1994, 1997). These are, from south to north, Puesto Estancia La Costa (= Corriguen Aike of older literature; Marshall, 1976), Cañadón Silva, Estancia La Costa, and Cañadón del Indio (= Punta Sur; Tauber, 1994). Again, based on the regional attitude of the beds, Tauber's interpretation is that these localities are superpositional from north to south—Puesto Ea. La Costa overlies Cañadón Silva, which overlies Ea. La Costa.

Tauber's hypothesis (1994) that the southern suite is younger than the northern is supported by the lithologic distinctness of the two and the regional attitude of the beds of the Santa Cruz Formation. However, his claim that the two suites also are faunally distinct and that the difference is a consequence of climatic change is open to question. The faunal distinctness is subject to challenge: Tauber's analysis includes only specimens collected by him and excludes specimens of known stratigraphic provenance collected by Hatcher, Brown, Martin, Riggs, and others (Marshall, 1976). Thus, as Fleagle et al. (2004) suggest, some of the faunal difference may be a consequence of limited sampling.

3. New localities

To the preceding list of localities, we now add two new ones north of Estancia La Costa, the first located more than 1 km from a beach access point.[1]

3.1. Anfiteatro

3.1.1. Geographic location

It is in the intertidal zone (~S 51°, 3.22′; W 69°, 8.30′), 3.3 km north of the entrance to the beach at Estancia La Costa (ELC) (Fig. 2A). Named for a large slump on the cliff above the fossiliferous beach exposures, the locality consists of two areas of exposure separated by a northeast–southwest cross-bedded channel sandstone. The southern exposure is approximately 8.5 ha in extent and the northern exposure is approximately 1.0 ha, as determined by GPS. This fossil locality has the greatest surface exposure of any along the coast between Coy inlet and Cabo Buen Tiempo and, unlike any of the others, all the fossils come from the same horizon. The southern margin of the exposure disappears into beach silt; a low scarp sculpted by marine erosion delimits the northern edge of the exposure.

3.1.2. Composition and structure

The fossil bed is a water-deposited tuffaceous silty clay. The bed varies in thickness up to a maximum of 2 m. When dry, its weathered surfaces are grayish-white to tan, but it is greenish-white in the unweathered state. Deposition must have been rapid, as a number of fossils were observed to extend up to 20 cm into the rock. Neither cross-bedding nor root casts are visible; the fossils lack obvious surface weathering at the time of deposition and often are found in a partially articulated state. It appears that this tuffaceous horizon was buried soon after deposition and before a paleosol could be established.

[1] Several fossil specimens collected by Hatcher, Riggs, and others housed in collections at Yale Peabody Museum and The Field Museum of Natural History are of uncertain provenience and from between Estancia La Costa and Cañadón del Indio. For example, Riggs mentions specimens from 5 to 7 miles south of Coyle Inlet; the Ea. La Costa locality is described as 8 miles south of Coyle inlet (Marshall, 1976). Likewise, Patterson (1958) mentions specimens collected by O.A. Peterson 5 miles south of Coy Inlet. Either of these could refer to Campo Barranca or Anfiteatro. Alternatively, these specimens could come from blocks of tuffaceous sandstone that have fallen to the beach somewhere between these points.

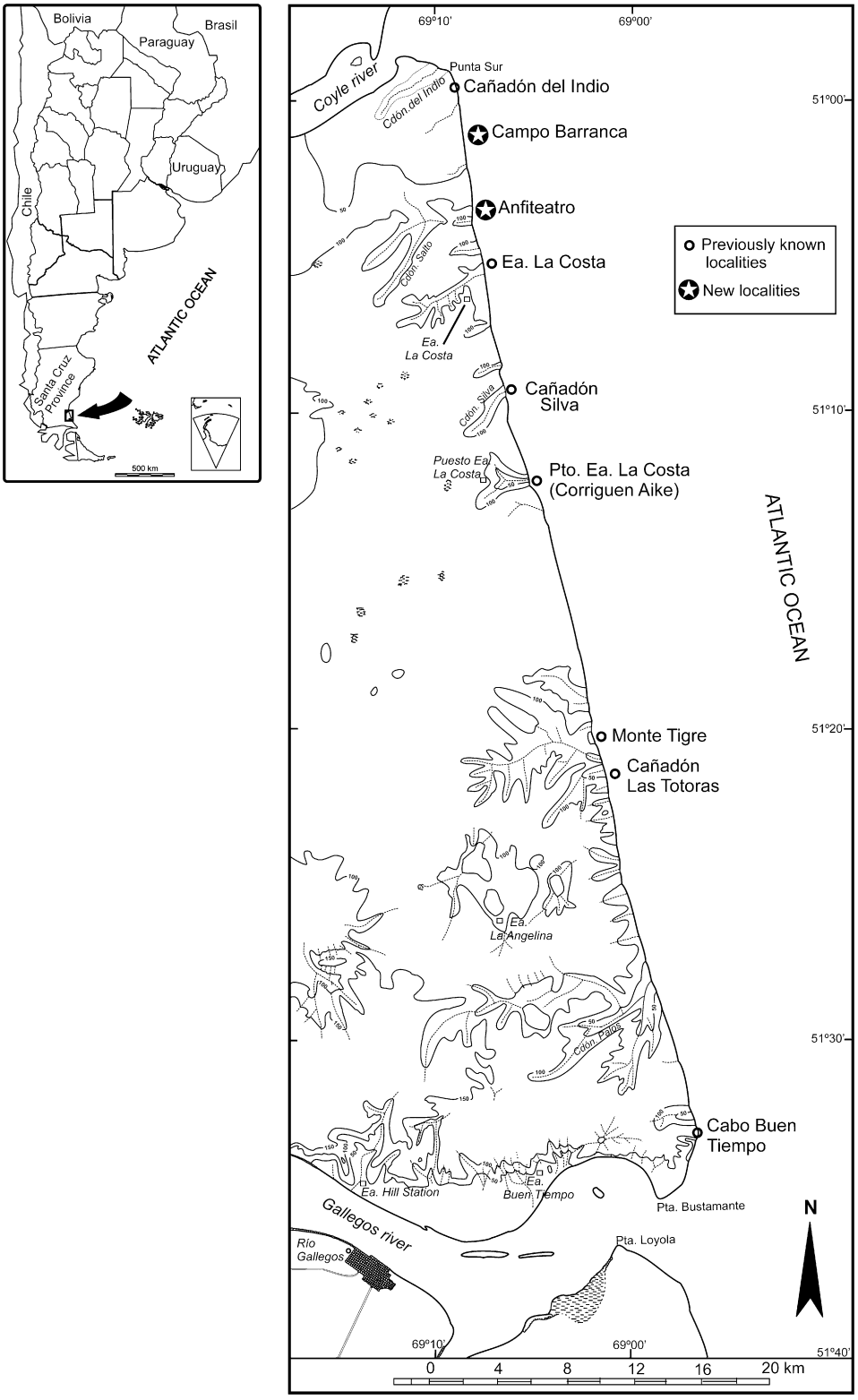

Fig. 1. Geographic locations of new and previously reported fossil localities in the Santa Cruz Formation along the 70 km stretch of the Atlantic coast from the inlet of Rio Gallegos in the south to Coyle Inlet in the north. Basemap: Carta Topografica de La Republica Argentina, Paso Coy Aike, Santa Cruz (hoja 5169-21), Puerto Coig, Santa Cruz (hoja 5169-15), and Río Gallegos, Santa Cruz (hoja 5169-27) escala 1:100,000; Ejército Argentino, Instituto Geográfico Militar, 1942.

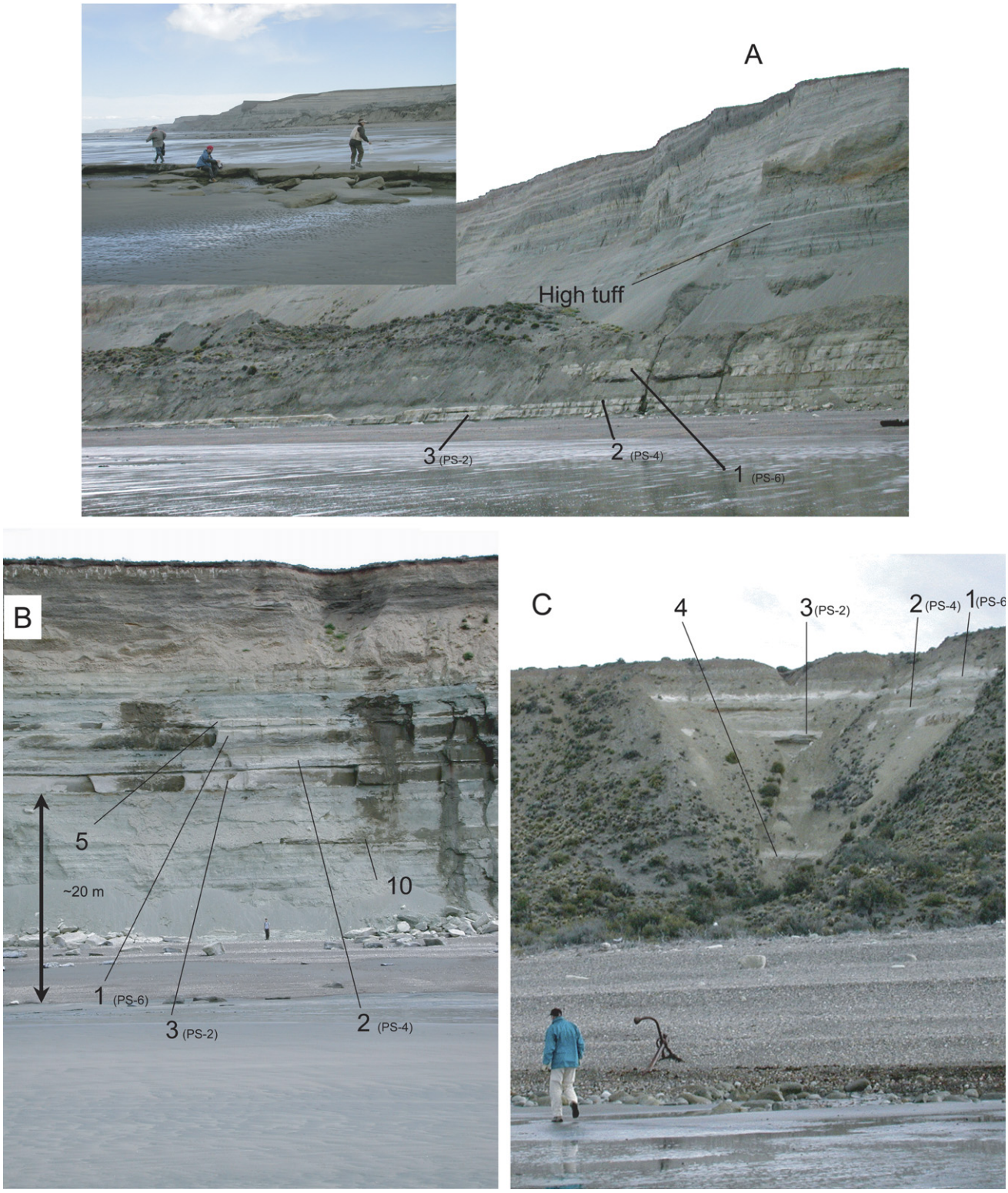

Fig. 2. New localities and exposures of the Santa Cruz Formation along the Atlantic coast. (A) Fossil horizon at Anfiteatro, inset into photograph of the tuff horizons that crop out approximately 0.5 km to the north. To the south (left in photograph), a large part of the cliff wall has slumped seaward, obliterating the layers superadjacent to the fossil locality. (B) Fossil horizon at Campo Barranca, inset into photograph of the tuff horizons that crop out along the cliff adjacent to it. (C) Tuff horizons that crop out at Cañadón del Indio near the inlet of Río Coyle. Tuff levels 1, 2, and 3 correspond to levels PS-6, PS-4, and PS-2 of Tauber (1994) and are continuously exposed between each of these points.

3.2. Campo Barranca

3.2.1. Geographic location

It is in the intertidal zone (S51°, 0.99′; W 69°, 9.00′), 7.7 km north of the entrance to the beach at Estancia La Costa (ELC) (Fig. 2B) and named for a parcel of land within the Estancia La Costa. The area of exposure of this locality is approximately 500 m north to south and 250 m east to west. It is bounded to the north by cross-bedded channel sandstones that yield only a few broken fossil vertebrates. Because of the cover to the west by beach silt and to the east by the sea, the temporally bounding rock units were not observed.

3.2.2. Composition and structure

The Campo Barranca fossil level is composed of a silty clay, greenish in color. In places, the clay is finely laminated—some layers have ripple marks and others are carbon-rich. Elsewhere, it is bioturbated, preserving calcified root casts, and has poorly defined bedding.

3.3. Stratigraphic position of Campo Barranca and Anfiteatro

Two distinct problems arise when determining the relative and absolute ages of the new localities. First, where do they fit relative to previously described localities (enumerated previously) south of Río Coyle? Second, what is their age relative to the Santa Cruz Formation faunas farther north at Mt. Observación[2] and Mt. León, for which there are several published radiometric dates?

3.3.1. Age relative to localities south of Río Coyle

The stratigraphic position of these new localities is best understood by comparison with three conspicuous white tuff marker beds that crop out at Cañadón del Indio and elsewhere along this cliff face (Fig. 2C). Tauber (1994, pp. 38–40) describes these three beds as water-lain bioturbated tuffaceous clays near the top of the cliff beneath a gravel layer (“rodados patagónicos”, Pliocene–Quaternary). These tuffs are identified (Tauber, 1994, pp. 38–40) as PS (Punta Sur) -6, PS-4, and PS-2. They, along with overlying and underlying tuff layers, can be traced discontinuously along a distance of 13 km, from Cañadón del Indio to the northern end of the slump at Anfiteatro.

> PS-6 (our tuff level 1), is 1–2 m thick and described as a “white tuff with quartz phenoclasts, well compacted with clean and sharp upper and lower contacts” (in translation). Tauber notes the existence of a specimen of *Interatherium* sp. (a small notoungulate) in PS-6 at Cañadón del Indio.
>
> PS-4 (our tuff level 2) is 1–2 m thick and is a “white tuff with quartz and heavy-mineral phenoclasts, compact with clean contacts.”
>
> PS-2 (our tuff level 3) is 1–2 m thick and is a “white compact tuff with clean and smooth contacts.”

Tauber (1994) reports 8 m of cineritic tuff (volcanogenic siltstones and claystones) interbedded between PS-6 and PS-4 and 11.5 m of the same material between PS-4 and PS-2. Farther south, the vertical separation between PS-6 and PS-4 is slightly greater than that between PS-4 and PS-2. The true dip of these beds is to the southeast. Based on the height of the uppermost tuff above the beach level, an average apparent dip of 0.3° was recorded over a distance of approximately 8.25 km on a bearing of 168°S. The eastward dip is similarly gentle, less than 1°. The strike is estimated to be approximately 25° (i.e., north–northeast).

Our conclusions regarding the positional relationships of the tuff layers are in basic agreement with those of Tauber (1994), but there are a number of complications. First, each of the individual tuffs decomposes at several places into several separate levels. At other places, the levels merge into what appears to be a single horizon, only to split again further along. Clearly, none of the major tuff layers represents a single depositional event; rather, a series of events is encompassed within each “tuff horizon.” Second, a number of major and minor tuff beds appear above and below the three identified by Tauber. Indeed, a fourth major tuff is visible at Cañadón del Indio; it is below PS-2. Fig. 3 summarizes the pattern of tuff horizons along the section.

Despite these complications, tuff layers PS-6, PS-4, and PS-2 are also visible on the cliff wall above the Campo Barranca fossil bed. The Campo Barranca fossil level is more than 20 m below the lowest cliff-wall tuff (equivalent to PS-2 at Cañadón del Indio); the latter is clearly visible on the cliff wall above and west of the locality (Fig. 2B). Farther south, PS-2 reaches the intertidal zone just at the northerly edge of Anfiteatro, and the fossil bed at Anfiteatro could be stratigraphic correlative of PS-4 or PS-2 (Fig. 2A).

The stratigraphic position of the Anfiteatro fossil bed relative to localities farther south is less certain. Tauber (1994, 1996, 1997) identifies three fossil levels at Estancia La Costa (ELC), which cannot be traced because of intervening slump deposits. Tauber proposes that the third fossil level (NF-3) at ELC is equivalent to the uppermost of the three Cañadón del Indio tuffs (PS-6), based on the assumption that the regional attitude of these beds is maintained. Because fossil levels 1 and 2 at ELC are lower than fossil level 3, it follows that fossil levels 1 and 2 at ELC must be equivalent to beds between tuffs PS-6 and PS-4.

[2] Within the Parque Nacional Monte León is a feature called Cerro Observación. Farther south, beyond the limits of the park, is another hill called Cerro Observatorio. The geographic feature referred to in the paleontology literature as Monte Observación (e.g., by Ameghino, Marshall, Fleagle, and Bown) pertains to the latter feature, which is further identifiable as within the drainage of Cañadon de las Vacas (Marshall, 1976, p. 1131).

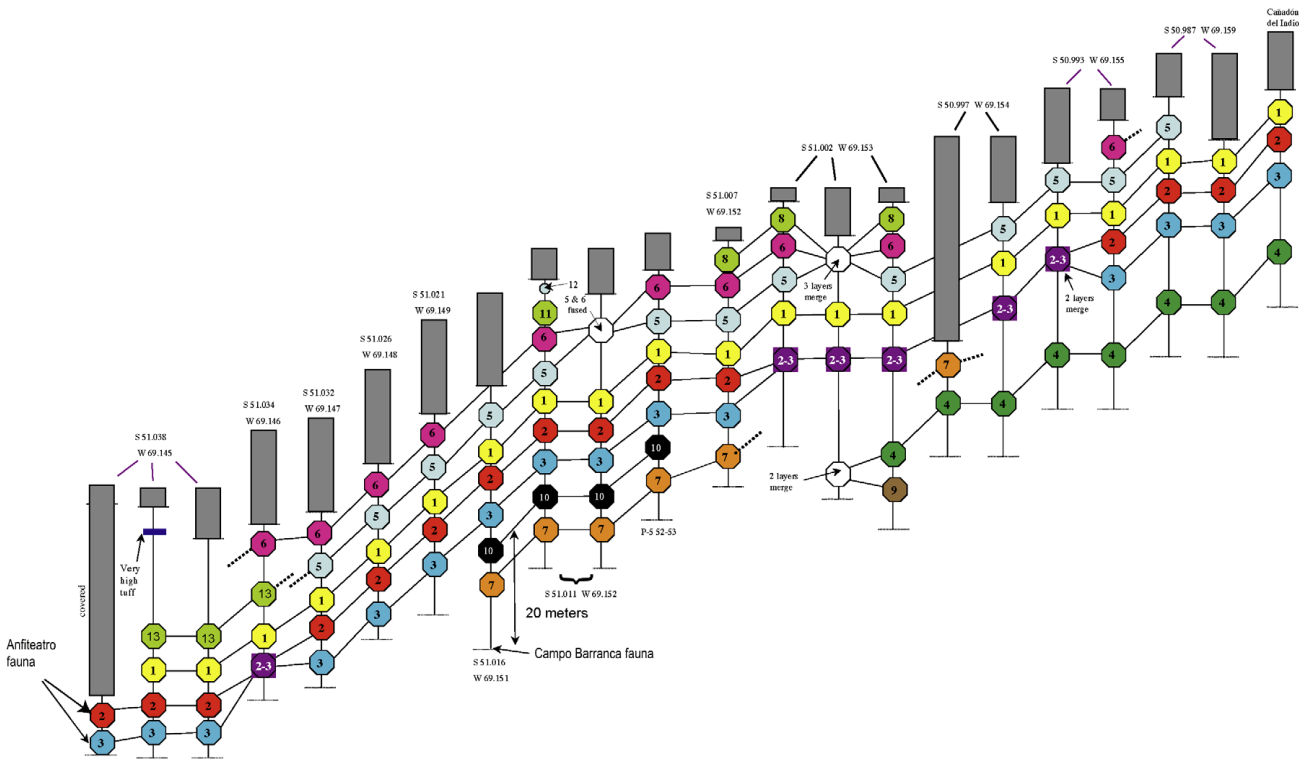

Fig. 3. Stratigraphic profile of tuff horizons in the Santa Cruz Formation cropping out along the cliff exposures between Cañadón del Indio (Fig. 2C) and Anfiteatro (Fig. 2A) based on 12 panoramic photocomposites. Longitudes and latitudes refer to the points at which the photographs were made (photographs available on request). Gray area at top of column indicates the gravels and sands overlying the Santa Cruz Formation. Dashed line at the bottom of the column indicates the beach level. Distances between the beds and total height of each column are schematic. Numbers refer to identifiable tuff layers in each profile. The beds are numbered according to their first appearance from north to south and from top to bottom. The position of the fossil localities Campo Barranca and Anfiteatro are indicated.

Because the fossiliferous level at Anfiteatro is visibly lower than tuff PS-4, the fossils at Anfiteatro must be older than any of the fossils discovered farther south. We accept this interpretation with caution.

Regional dip may not be the only plausible explanation for positional changes in these beds along the section. It is equally plausible that the attitude of these beds undergoes local variation and that the tuffs exposed in the fossiliferous horizons at ELC, Cañadón Silva, and PLC are the same ones as those on the cliff wall at Cañadón del Indio. Each of these intertidal localities is stratigraphically separated from the others by slumps. We refrain from drawing a conclusion on this point pending full publication of geochemical analyses of the tephra (see abstract by Fleagle et al., 2004).

3.3.2. Age relative to Mt. Observación and Mt. León.

The Santa Cruz Formation crops out at Monte Observación and Monte León. These are hills 60–90 km north of Río Coyle. The stratigraphy and age of these deposits are described by Bown and Fleagle (1993). At Mt. León, the marine Monte León Formation underlies the Santa Cruz Formation. At Mt. Observación, this contact is not exposed. A sequence of tuffacious horizons crops out low in the sections at both areas and has been dated at about 16.3 Ma (Fleagle et al., 1995). It is plausible that the lower tuff levels correlate to the marker horizons at Cañadón del Indio, because Tejedor et al. (2006) suggest one of them might be the same as the tuff layer at Killik Aike Norte, a site on the north shore of the estuary of Río Gallegos. However, further geochemical study is needed to test this potential correlation of Killik Aike Norte with Monte Observación. Killik Aike Norte is southeast of the coastal localities mentioned previously, so at least one of the Mt. Observación tuffs had sufficient aerial extent to have been encountered in our area of study.

If it proves to be the case that the principal tuff levels at Cañadón del Indio are correlatives of marker horizons at Mt. Observación and Mt. León, this finding would have important implications for the age of Campo Barranca fossils. The tuff horizons are within 15 m of the base of the exposed continental section at Mt. Observación and Mt. León. Therefore, Campo Barranca is at least as old as any locality from the coastal Santa Cruz Formation, and probably older. This possibility raises the prospect of encountering a fauna that is at least partially contemporaneous with the Pinturas Formation farther west in Santa Cruz Province, dated between 17.5 and 16.5 Ma (Fleagle et al., 1995).

4. Faunal lists

Table 1 summarizes the faunal list for Anfiteatro and Campo Barranca based on our specimens. This list will expand as previously collected specimens are prepared and with future collecting. At the moment, this faunal list fits within the Santacrucian SALMA (Marshall, 1976; Marshall et al., 1983).

5. Discussion

Anfiteatro and Campo Barranca join previously discovered fossil vertebrate localities in coastal exposures of the Santa Cruz Formation, south of 51° latitude, to document a faunal assemblage very different from that of any living mammalian community. In particular, the high level of mammalian species richness in a region so far from the Equator poses a challenge to prevailing theories that attempt to account for diversity as a function of plant productivity (e.g., Kay et al., 1997; Rozenzweig and Abramsky, 1993).

The abundance of well-preserved mammalian fossils at Anfiteatro in particular offers an unusual window for reconstructing the structure of a South American mammalian community. An ecomorphological approach, based on precise or detailed functional analysis in a well-defined phylogenetic framework, is most promising for generating such community reconstructions (see Kay and Madden, 1997; Kay et al., 2004; Vizcaino et al, 2006; Williams and Kay, 1999). For this purpose, we need a temporally precise, intensively sampled collection that documents as much of the skeleton as possible for many species; these localities promise to yield such faunas.

The new localities come from the lowest part of the Santa Cruz Formation exposed on the Atlantic coast. At Mt. Observación and Mt. León farther north, the base of the formation is variably conformable and unconformable on the nearshore marine Mt. León Formation (Bown and Fleagle, 1993). At those places, the base of the formation comes just a few meters below the lowest volcanic tuff, possibly correlated with one or more of the main tuff layers at Cañadón del Indio and farther south at Killik Aike Norte on the estuary of the Río Gallegos (Tauber et al., 2004; Tejedor et al., 2006). If this correlation is confirmed, Anfiteatro would be among the lowest localities stratigraphically in the formation, and Campo Barranca probably would be the lowest. This lower position and greater antiquity suggests a correlation with faunas of the somewhat older Pinturas Formation. Dates from the Santa Cruz Formation at Mt. Observación, Mt. León, and Killik Aike Norte are all younger than 16.5 myr, whereas those from Pinturas are between 16.5 and 17.5 myr (Fleagle et al., 1995; Tejedor et al., 2006). As noted by Fleagle et al. (1995), p. 129, "the precise relationship between the Pinturas Formation and the base of the Santa Cruz Formation at Monte Observación requires further investigation." Among other recently reviewed faunal elements, the primates (Fleagle, 1990; Fleagle et al., 1997; Tejedor et al., 2006), paucituberculate marsupials (Bown and Fleagle, 1993; Dumont et al., 2000; Rae et al., 1996), and rodents (Kramarz, 2002, 2004) should show important differences. Study and identification of the specimens in hand and planned further collect-

Table 1
Preliminary faunal lists for Anfiteatro and Campo Barranca (2006, 2007)

ANFITEATRO (ANF = 107 specimens)

AVES

Indet

MAMMALIA

MARSUPIALIA
- Hathlyacynidae
  - Hathlyacynidae indet small species
  - *Cladosictis patagonicus*
- Borhyaenidae
  - *Borhyaena* cf. *B. tuberata*

XENARTHRA

Cingulata
- Glyptodontidae
  - *Propalaehoplophorus* sp.
- Peltephilidae
  - *Peltephilus* cf. *P. pumilus*
- Dasypodidae
  - *Proeutatus* sp.

Tardigrada
- Tadigrada indet

RODENTIA

Cavioidea
- Eocardiidae
  - *Eocardia* sp.
- Dasyproctidae
  - *Neoreomys* sp.

Octodontoidea
- Acaremyidae
  - *Sciamys* sp.
- Echimyidae
  - *Spaniomys modestus*

LITOPTERNA
- Macraucheniidae
  - *Diadiaphorus* sp.

NOTOUNGULATA
- Typotheria
  - Interatheriidae
    - *Interatherium* sp.
- Hegetotheria
  - Hegetotheriidae
    - *Hegetotherium* sp.
- Toxodontia
  - Toxodontidae
    - *Nesodon* sp.
    - *Nesodon imbricatus*
    - *Adinotherium* sp.
    - *Adinotherium ovinum*

ASTRAPOTHERIA
- *Astrapotherium* sp.

PRIMATES
- *cf. Homunculus*

CAMPO BARRANCA (CB = 95 specimens)

AVES

"Phorusrhacidae"

MAMMALIA

MARSUPIALIA
- Paleothentidae
  - *Paleothentes minutus*

XENARTHRA

Cingulata
- Dasypodidae
  - *Proeutatus* sp.
  - *Prozaedyus* sp.
  - *Stenotatus patagonicus?*

Tardigrada
- cf. *Hapalops*
- *Eucholoeops* sp.

RODENTIA

Chinchilloidea
- Neoepiblemidae
  - *Perimys* sp.

Cavioidea
- Eocardiidae
  - *Eocardia* sp.
- Dasyproctidae
  - *Neoreomys* sp.

Octodontoidea
- Echimyidae
  - *Spaniomys modestus*
  - *Stichomys* sp.

NOTOUNGULATA
- Typotheria
  - Interatheriidae
    - *Protypotherium* sp.
    - *Protypotherium* cf. *P. attenuatum*
- Toxodontia
  - Toxodontidae
    - *Adinotherium* sp.
    - *Adinotherium ovinum*

ing should tell us whether the unusual faunal elements that now distinguish the faunas of the Pinturas Formation from coastal Santa Cruz Formation are also present in the lower and older localities farther south and east (e.g., Anfiteatro and Campo Barranca).

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