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The Upper Cretaceous – Lower Tertiary marine to continental transition in the Bagua basin, northern Peru

Paleontology, biostratigraphy, radiometry, correlations

by THOMAS MOURIER, PETER BENGTSON, MICHEL BONHOMME, EMILE BUGE, HENRI CAPPETTA, JEAN-YVES CROCHET, MONIQUE FEIST, KARL F. HIRSCH, ETIENNE JAILLARD, GÉRARD LAUBACHER, JEAN PHILIPPE LEFRANC, MICHEL MOULLADE, CHRISTOPHE NOBLET, DENISE PONS, JACQUES REY, BERNARD SIGÉ, YVETTE TAMBAREAU and PHILIPPE TAQUET*

with 3 figures and 4 tables

Abstract. Various fossils (invertebrates, vertebrates, plants) and radiometric data have been obtained from the uppermost part of the marine Celendin Fm. and the lowermost part of the overlying Bagua Fm. (redbeds). After description of the stratigraphy and sampled localities, the fossils are discussed in terms of systematics, biostratigraphy, paleoecology and biogeography. On the basis of ammonites, the uppermost Celendin Fm. is dated as mid-Campanian. On the basis of a charophyte assemblage and other evidence,

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* Authors' addresses: P. BENGTSON, Paleontologiska museet, Uppsala universitet, Box 558, S–751 22 Uppsala, Sweden.
M. BONHOMME, Institut Dolomieu, UA 69, rue M. Gignoux, F–38031 Grenoble Cedex, France.
E. BUGE and PH. TAQUET, Institut de Paléontologie, UA 12, Muséum Natl. d'Histoire Naturelle, 8 rue Buffon, F–75005 Paris, France.
H. CAPPETTA, J.-Y. CROCHET, M. FEIST and B. SIGÉ, Institut des Sciences de l'Evolution, UA 327, U.S.T.L., Place Eugène Bataillon, F–34060 Montpellier Cedex, France.
K. F. HIRSCH, Museum, University of Colorado, Henderson Building, Campus Box 218, Boulder, Colorado 80309, U.S.A.
E. JAILLARD, Institut Dolomieu, rue M. Gignoux, F–38031 Grenoble Cedex, France.
G. LAUBACHER, ORSTOM, 213 rue de La Fayette, F–75480 Paris Cedex 10, France.
J. PH. LEFRANC, C. G. G., U.S.T.L., Place Eugène Bataillon, F–34060 Montpellier Cedex, France.
M. MOULLADE, Laboratoire Micropaléontologie et Géologie marines, Université Nice, Parc Valrose, F–06034 Nice Cedex, France.
TH. MOURIER, Laboratoire de Géologie Historique, Université Paris Sud, Bat. 504, F–91405 Orsay, France.
CH. NOBLET, Mission ORSTOM, Apartado 6596, C.C.I., Quito, Ecuador.
D. PONS, Laboratoire Paléobotanique, Université Paris 6, 12 rue Cuvier, F–75005 Paris, France.
J. REY, Laboratoire Géologie sédimentaire et Paléontologie, 39 Allées Jules Guesde, F–31062 Toulouse Cedex, France.
Y. TAMBAREAU, Laboratoire Géologie-Pétrologie, Université Paul Sabatier, 38 rue des Trente-six ponts, F–31400 Toulouse Cedex, France.

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the lowermost Bagua Fm. (Fundo El Triunfo Member) is dated as mid-Campanian to early Maastrichtian. Higher in the section, a layer of the Sambimera Member has yielded another charophyte assemblage characteristic of the Early Tertiary. These data are consistent with a K-Ar age of 66.0 ± 1.6 Ma obtained from an overlying volcanic tuff. In this Andean area, the emergence is dated as late Campanian to early Maastrichtian. The Peruvian tectonic phase, characterized by a weak unconformity between the F.E. Triunfo and the Rentema Members, seems to be somewhat younger, late Campanian to Maastrichtian. The Cretaceous – Tertiary boundary is restricted to the 170 m thick section between the two charophyte bearing layers. From the north of Peru to the south of Bolivia, the charophytes provide the main support for a rather constant and consistent double correlation between, first: units referred to the Campanian – Maastrichtian (F.E. Triunfo, Arenisca de Azucar, Sol 1, K'ayra, Soncco, Vilquechico, El Molino) and, second: units referred to the Paleocene – Lower Eocene (Sambimera, Upper Sol 3, Contamana, Puna Cancha, Muñani, Santa Lucia).

Résumé. Dans le synclinal de Bagua, le sommet de la Fm. marine Celendin et la base de la Fm. Bagua sus-jacente (couches rouges) ont livré des fossiles nombreux et variés (invertébrés, vertébrés, végétaux) et des données radiométriques. Après la description de la stratigraphie et des localités, les fossiles sont discutés en termes de systématique, biostratigraphie, paléoécologie, et biogéographie. Sur la base des ammonites, le sommet de la Fm. Celendin est considéré d'âge campanien moyen. D'après une association de charophytes et d'autres arguments, la base de la Fm Bagua (Membre Fundo El Triunfo) est considérée d'âge campanien moyen à maastrichtien inférieur. Plus élevé dans la série, un horizon du Membre Sambimera fournit une autre association de charophytes, caractéristique du Tertiaire inférieur. Ces données sont cohérentes avec un âge K-Ar de 66.0 ± 1.6 Ma obtenu sur un tuf volcanique sus-jacent. L'émersion de cette zone andine est datée du Campanien inférieur à Maastrichtien inférieur. La phase tectonique Péruvienne, caractérisée par une faible discordance entre les Membres F.E. Triunfo et Rentema, apparaît plus récente, d'âge campanien tardif à maastrichtien. La limite Crétacé – Tertiaire est circonscrite dans les 170 m de la coupe séparant les deux niveaux à charophytes. Ces végétaux fournissent le principal support d'une double corrélation assez constante et cohérente depuis le Nord du Pérou jusqu'au Sud de la Bolivie, entre d'une part des unités référées au Campano – Maastrichtien (F.E. Triunfo, Arenisca de Azucar, Sol 1, K'ayra, Soncco, Vilquechico, El Molino) et d'autre part des unités référées au Paléocène – Eocène inférieur (Sambimera, Sol 3 supérieure, Contamana, Puna Cancha, Muñani, Santa Lucia).

Resumen. En el sinclinorio de Bagua, el tope de la Fm. marina Celendin y la base de la Fm. Bagua (Capas Rojas) que la sobreyace, contienen numerosos y variados fósiles (invertebrados, vertebrados, vegetales) y niveles de tufos volcánicos sobre uno de los cuales se ha obtenido edades radiométricas. Después de la descripción de la estratigrafia de muestro, los fósiles se discuten en terminos de sistemática, bioestratigrafía, paleoecología y biogeografiá. En base a ammonites, el tope de la Fm Celendin se attribuye al Campaniano medio. Una asociación de carofitas y otros argumentos llevan a proponer una edad Campaniano medio hasta Maastrichtiano inferior para la base de la Fm Bagua (Miembro Fundo El Triunfo). En una capa del Miembro Sambimera que sobreyace al Miembro F.E. Triunfo se ha recolectado una otra asociación de carofitas característica del Terciario inferior. Estos datos son coherentes con la edad K-Ar de 66.0 ± 1.6 Ma obtenida sobre un tufo intercalado en el Miembro Sambimera unos metros por encima de las capas con carofitas. La emersión de esta zona andina se produce entre el Campaniano inferior y el Maastrichtiano inferior. La tectonica Peruana, caracterizada por una leve discordancia entre los Miembros F.E. Triunfo y Rentema es posterior a la emersión y occure en el Campaniano tardío – Maastrichtiano. El limite Cretácico – Tertiario se localiza dentro de los 170 m de sedimentos separando los dos niveles con carofitas. Estos vegetales proveen una base esencial para una doble correlación, bastante coherente y constante, desde el norte del Perú hasta el sur de Bolivia, entre las unidades attribuidas al Campaniano – Maastrichtiano (F.E. Triunfo, Arenisca de Azucar, Sol 1, K'ayra, Soncco, Vilquechico, El Molino) por una parte, y las unidades attribuidas al Paleoceno – Eoceno inferior (Sambimera, Sol 3 superior, Contamana, Puna Cancha, Muñani, Santa Lucia) por otra parte.

Contents

Introduction

In the Peruvian sector of the Central Andes, Upper Cretaceous marine carbonate strata are conformably to disconformably overlain by continental redbeds of Late Cretaceous to Early Tertiary age. This redbed sedimentation is one of the most conspicuous features of the Andean orogenic evolution. Reflecting the emergence of the Andean active margin, it was classically considered a consequence of the Late Cretaceous "Peruvian" compressionnal phase (STEINMANN 1929, BENAVIDES-CÁCERES 1956). Well dated folding of this age is however poorly documented and restricted to a few areas of the Western Cordillera (VICENTE et al. 1979). Intense Peruvian deformation in the Eastern Cordillera of Central Peru (MÉGARD 1973, 1978) is now questioned (SOLER & BONHOMME 1987), and it seems that in this area Upper Cretaceous marine strata commonly grade transitionally into Upper Cretaceous redbeds or are disconformably overlain by them. In any case the precise age of the Peruvian phase and of Late Cretaceous emergence remains badly constrained and thus the transition from marine to continental deposition and the Peruvian orogenic event were implicitely considered to be both manifestations of the same geologic event. Most of the authors (STEINMANN 1929, BENAVIDES-CÁCERES 1956, WILSON 1963, COBBING et al. 1981, JANJOU et al. 1981) assumed a Coniacian to Santonian age for this event in northern Peru.

A highly fossiliferous and fairly complete stratigraphic record of the Late Cretaceous to Early Tertiary sedimentation was discovered recently in the Bagua syncline of Northern Peru at about 5°30′ S and 78°30′ W (Fig. 1–2), where a well exposed section is deeply dissected by the Marañon river at Pongo de Rentema. The marine strata of the Bagua syncline are situated geographically between the Mesozoic marine deposits of the northern end of the West Peruvian trough (Andean basin) and those of the East Peruvian trough (COBBING et al. 1981) (Subandean basin). In the central part of the syncline Cretaceous marine beds are overlain by more than 3000 m of continental detrital strata (SALAZAR 1973) of latest Cretaceous and Tertiary age, with some intercalations of reworked silicic tuffs.

MOURIER et al. (1986) assumed an early Santonian age for the uppermost marine strata in the Bagua basin based on a preliminary identification of an ammonite assemblage, and therefore assumed a late Santonian age for the emergence of the basin.

In this paper, we present the results of more detailed investigations on various plant, invertebrate and vertebrate fossils from the uppermost Cretaceous marine strata and the overlying Upper Cretaceous to Lower Paleogene continental redbeds. Detailed study of the ammonites indicates a mid-Campanian age for the uppermost marine strata which suggest a mid-Campanian to early Maastrichtian age for the emergence in the Bagua area. In addition, according to two charophyte assemblages and a preliminary K-Ar dating of a silicic volcanoclastic bed, the position of the Cretaceous – Tertiary boundary can be constrained between the Fundo El Triunfo Member and the level dated Paleocene in the lower part of the Sambimera Member.

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Geological mapping and investigations began in the Bagua area during 1983 (T. MOURIER and E. JAILLARD, IFEA). In August 1984, T. MOURIER (IFEA), G. LAUBACHER, C. NOBLET (ORSTOM) and A. QUIROZ (Univ. Nac. Ing. Lima) discovered dinosaur remains at Pongo de Rentema in the basal Late Cretaceous redbeds. In november 1984, B. SIGÉ (CNRS–UA 327, Montpellier) undertook a first trip in the Bagua area in order to obtain more fossil data. In 1985, another trip in the Bagua syncline allowed B. SIGÉ and J.-Y. CROCHET to recover more material and to prospect more localities of the Late Cretaceous and Early Tertiary formations of the Bagua basin.

Paleontological processing and geochronological analyses were supported by ASP Evolution (CNRS), UA 69 (CNRS) and ORSTOM. We are indebted to B. MARANDAT for paleontological processing and translation work, and to B. ORTH for drawing. B. SIGÉ and G. LAUBACHER coordinated the Bagua project and the preparation of this paper.

Fig. 1. Western Central South America: major Andean areas discussed in the paper and Late Cretaceous sedimentation in the Central Andes. 1 continental redbeds; 2 marine or brackish strata; 3 volcanism (modified from Dalmayrac et al. 1980, Martinez 1980, Salfity & Marquillas 1986).

I Stratigraphy (G. Laubacher & Th. Mourier)

In the Andes of northern Peru, the stratigraphic features of the Cretaceous marine carbonate platform sedimentary sequence and its subdivision into formations were established by Benavides-Cáceres (1956) in the Cajamarca area some 150 km south of Bagua (Fig. 1). The uppermost Cretaceous marine formation, the Celendin Formation shown by Benavides-Cáceres (1956) to contain rocks of Coniacian and early Santonian age, is also present in the Bagua syncline (Cordova 1985, Jaillard 1987).

At Pongo de Rentema, the Celendin Formation consists of 200 m of ochre marls and 80 m of black shales: in both lithologies, thin (30 to 80 cm thick) calcareous beds containing ammonites, pectens, oysters and gastropods, are common. The overlying Upper Cretaceous and Paleogene redbeds have not previously been named and here we name them the Bagua Formation as a preliminary assessment. The Bagua Formation is, at least in part, older than the Chota redbeds of the Cajamarca area (Benavides-Cáceres 1956) wich have yielded radiometric ages of about 50 to 44 Ma (Noble et al., in progress).

In Fig. 2, we present a simplified stratigraphic column of the upper part of the Celendin Formation and the lower part of the Bagua Formation valid for the Pongo de Rentema section and adjacent zones of the Bagua syncline. The stratigraphic position of the different faunas and volcanic intercalations is plotted in this column that comprises from bottom to top:

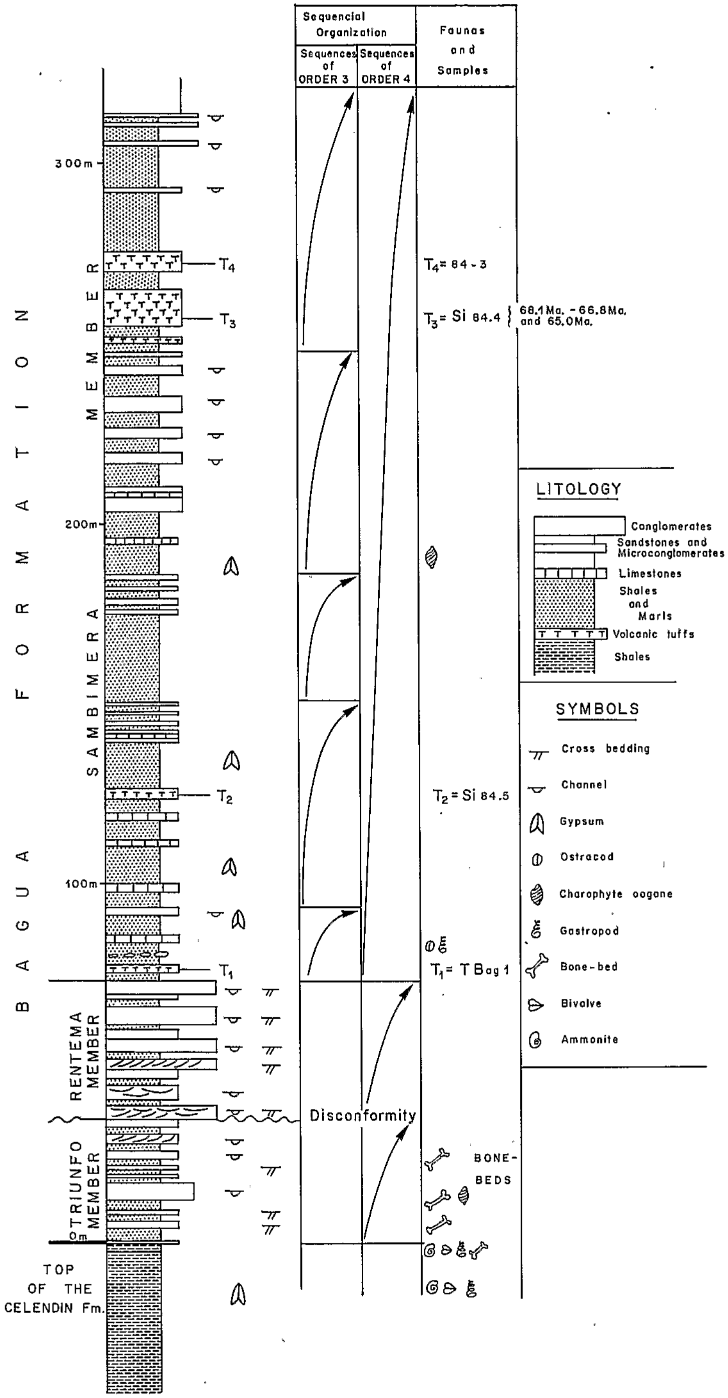
The Celendin Formation. The uppermost 40 meters of the formation are represented in the column (Fig. 2). They consist of black shales rich in secondary gypsum, sulfur and pyrite. Special attention has been paid to the faunas of the uppermost 10 meters.

The boundary strata between the Celendin and Bagua Formation are not exposed at Pongo de Rentema. However at Fundo El Triunfo, Morerilla and El Pintor localities, the boundary is transitional and represented by 2–3 m of sandy and marly redbeds with intercalated marine horizons. These transitional levels contain gastropods, bivalves, ammonites, and large bones fragments.

The Bagua Formation consists of a more than 1000 m thick pile of redbeds that can be divided at least into three members. Fig. 2 shows the lower 300 m of the Bagua Formation that includes the Fundo El Triunfo and Rentema Members and the lower part of the Sambimera Member.

– Fundo El Triunfo Member is a megasequence made of 10 to 70 m of plurimetric, little scale sequences of microconglomerates, sandstones and marls. The microconglomerates, consisting of algal crust fragments, form massive beds with erosion base. The sandstones are meter thick, upward fining beds. The purplish silty marls contain concretionary carbonate and algal crusts. Laterally, thickness changes rapidly: at Fundo El Triunfo it is less than 10 m, whereas in other parts, more than 70 m were measured. At Pongo de Rentema, associated vertebrae of a titanosaurid dinosaur were found at the base of the microconglomeratic beds (Mourier et al. 1986).

Fig. 2. Stratigraphic column of the marine late Cretaceous to the continental early Paleocene in the Bagua syncline.


Sequencial Organization
Sequences of ORDER 3
Sequences of ORDER 4
Faunas and Samples
300m
200m
100m
0m
T4
T3
T2
T1
T4 = 84-3
T3 = Si 84.4
68.1 Ma. - 66.8 Ma. and 65.0 Ma.
T2 = Si 84.5
T1 = T Bag 1
BONE-BEDS
Disconformity
BAGUA FORMATION
MEMBER
SAMBIMERA MEMBER
RENTEMA MEMBER
TRIUNFO MEMBER
TOP OF THE CELENDIN Fm.
LITOLOGY
Conglomerates
Sandstones and Microconglomerates
Limestones
Shales and Marls
Volcanic tuffs
Shales
SYMBOLS
Cross bedding
Channel
Gypsum
Ostracod
Charophyte oogone
Gastropod
Bone-bed
Bivalve
Ammonite

– Rentema Member is a topographically salient 10 to 90 m thick megasequence of massive beds of conglomerates, microconglomerates and sandstones that overlies with a slight unconformity the F.E. Triunfo Member. The base of the beds is strongly erosive and crossbedding is common. The megasequence shows a clear strata and grain coarsening upward. The unconformity and the high energy caracteristics of the fluvial sedimentation are the first evidence of a significative tectonic activity in the Bagua area.

– Sambimera Member is a more than 800 meters thick megasequence of lacustrine and alluvial sediments, that overlies conformably the Rentema Member. However this abrupt change from fluvial to lacustrine conditions indicates a sedimentary break of a possible climatic origin. In our stratigraphic column only the lowermost 250 m of the Sambimera Member are represented. They consist mainly of lacustrine variegated shales with gypsum and interbedded limestones, sandstones and tuffs. Few thin limestone beds are present in the lowermost 150 m of the Sambimera Member. One of them contains charophyte and ostracod remains. Sandstone beds are scarce in the lower part of the lacustrine sediments and become progressively sandier and microconglomeratic upward, grading into alluvial strata. Acid volcanism was active and tuffs are interbedded at different levels of the Sambimera Member (see Fig. 2). One level (T3) provided a radiometric age of 66.0 ± 1.6 (M. BONHOMME, this paper). The Bagua Formation is disconformably overlain by more than 2000 m of unnamed alluvial conglomerates.

Localities

Surface collecting of fossils, sampling of fossiliferous sediments to be screen-washed and sorted, and sampling of volcanic tuffs for radiometric dating were done at several localities. These were named from the map indications when available, or from indications provided by the campesinos. The localities shown in Fig. 3 are listed below, with short descriptions and topographic indications.

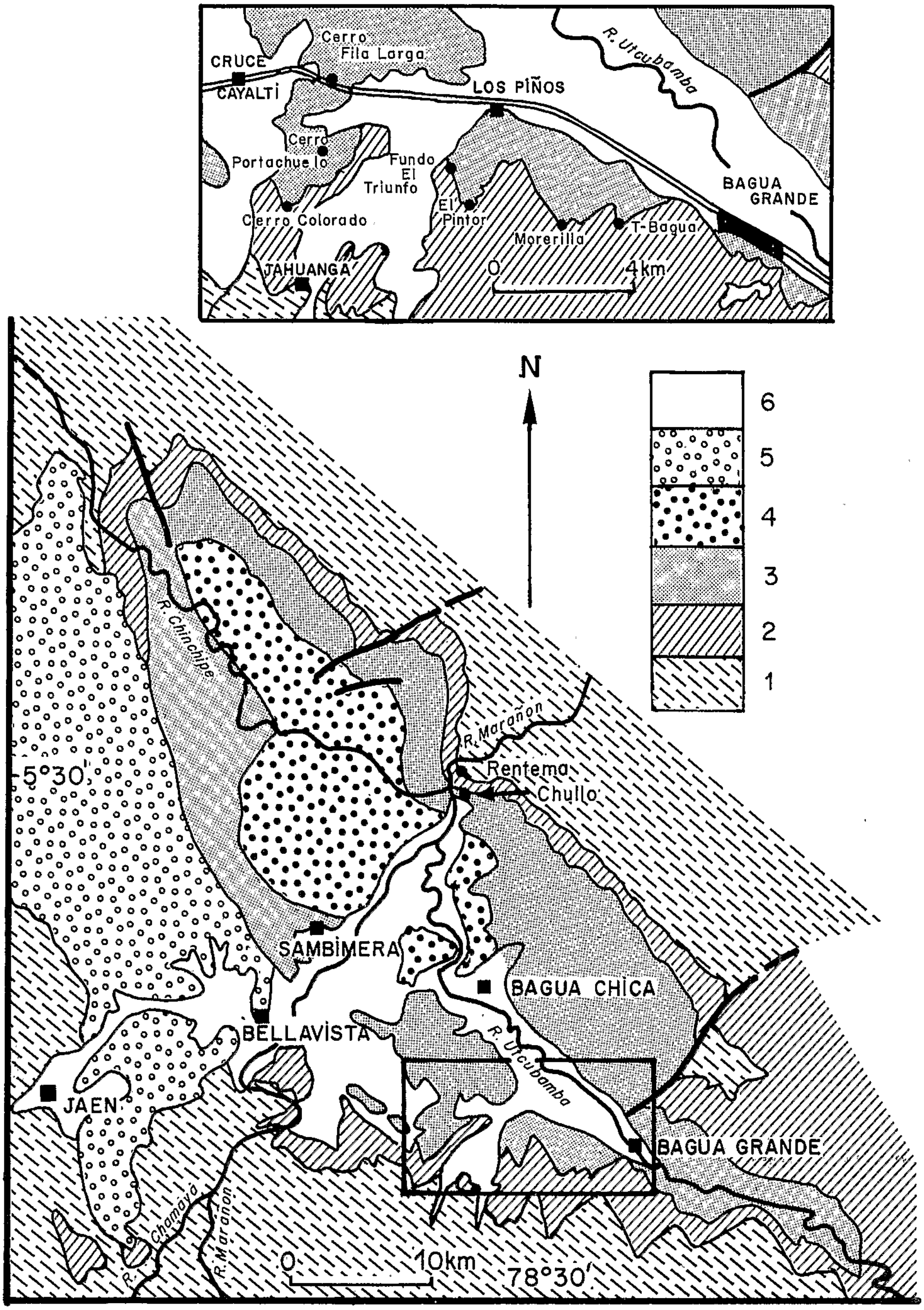
Bagua Grande (no map available; 5°46′00″ – 78°25′00″)

A hill immediately S of the town, above the last street, is a small outcrop of the basal redbeds of the Bagua Fm. A fragment of a large dinosaur bone was found at the top.

Cerro Colorado (map Jaen, Carta nacional 1/100000, Hoja 12–f; 5°45′00″ – 78°34′00″)

The uppermost layers of the Celendin Fm. and the basal redbeds of The Bagua Fm. are exposed in the low pass between Cerro Colorado and Cerro Portachuelo, 6 km SE from

Fig. 3. Simplified geological maps and localities of the Bagua area. 1 Cretaceous rocks older than the Celendin Formation; 2 Celendin Formation (Santonian to mid-Campanian); 3 Bagua Formation (mid-Campanian to Eocene?); 4 alluvial conglomerates overlying the Bagua Formation (Oligocene to Miocene?); 5 Bellavista conglomerates (Neogene?); 6 Quaternary alluvial sediments.


Cerro Fila Larga
CRUCE CAYALTI
LOS PIÑOS
R. Utcubamba
Cerro Portachuelo
Fundo El Triunfo
El Pintor
Cerro Colorado
Morerilla
T-Bagua
BAGUA GRANDE
JAHUANGA
0 4km
N
6
5
4
3
2
1
R. Chinchipe
R. Marañon
Rentema
Chullo
5°30'
SAMBIMERA
BAGUA CHICA
BELLAVISTA
R. Utcubamba
JAEN
BAGUA GRANDE
R. Chamaya
R. Marañon
0 10km
78°30'

Cruce Cayalti (main road Jaen – Bagua Grande), 300 m NE from the track to Jahuanga houses.

Cerro Fila larga (map Jaen; 5°42′30″ – 78°33′30″)

A white volcanic tuff, 15 to 20 m thick, forms a conspicuous bank in the landscape. It is crossed slantwise by the main road, 5 km E from Cruce Cayalti. It represents the third tuff (T3) recognized in the section, more or less 250 m above the Celendin Fm. – Bagua Fm. boundary (samples BG 84–11 and Si 84–4).

Cerro Portachuelo (map Jaen; 5°43′40″ – 78°32′00″)

Thick gypseous purple clays form the NE hillside of Cerro Portachuelo, 3 km S from the main road Jaen – Bagua Grande. On the track to Jahuanga houses, a 10 cm thick crumbly limestone level crops out on the right side of a sharp curve. It consists of charophyte oogones and ostracod shells. Rare scale fragments of vertebrates occur.

El Chullo (map Jaen; 5°31′10″ – 78°32′40″)

A white, 10 m thick volcanic tuff, with upright dip, forms an outcrop E side of the main road, 2 km S from Rentema houses. It is recognized as the second tuff (T2) in the studied section, 120–130 m above the Celendin Fm. – Bagua Fm. boundary (samples Si 84–5 and T–REN 85–1).

El Pintor (no map available; immediatly E of map Jaen; 5°44′30″ – 78°30′00″)

The uppermost layers of the Celendin Fm., the Celendin Fm. – Bagua Fm. boundary, and the basal redbeds of the Bagua Fm. are well exposed on the last S and SE hillsides of a large cerro made of red, yellow and purple beds, W side of the valley Quebrada Seca 1 km NE from the hacienda El Pintor. A direct track is issued from the main road Jaen – Bagua Grande, 1 km E from Los Piños.

Fundo El Triunfo (map Jaen; 5°44′30″ – 78°30′40″)

The same sequence is well exposed on the NW hillside of the same cerro, on the E side of the track issued from Los Piños, 1 km SE from the Fundo El Triunfo houses.

Morerilla (no map available; E of map Jaen; 5°45′00″ – 78°28′30″)

So called are large exposure areas of the same sequence: these are SW, S, and SE hillsides of a cerro made of red and yellow beds, E side of the valley Quebrada Seca. Vertebrate remains are abundant in small gulches on SE slope. A track is issued from the main road in front of the morerilla factory near Bagua Grande (first and second branchings on right, third on left).

Pongo de Rentema (map Jaen; 5°30′30″ – 78°33′00″)

Whereas the uppermost Celendin Fm. levels and the boundary are covered, the basal redbeds, with upright dip, are well exposed at the entry of the pass (pongo) of Rentema, above the main road to Chiriaca and the forest region. The charophyte association, selachian teeth, and eggshell material were obtained from the same layer, at the same locus, where associated vertebrae of a titanosaurid dinosaur were found (Mourier et al., o.c.).

T-Bagua (no map available; E of map Jaen; 5°44′30″ – 78°27′15″)

The Celendin Fm. – Bagua Fm. boundary, and basal redbeds containing bone fragments are exposed on the northern hillside of a small cerro, a few kilometers E from Bagua Grande (first branching on left on the track issued in front of the morerilla factory). A white to brown 10 m thick volcanic tuff is exposed 30 m above the Celendin Fm. – Bagua Fm. boundary. It is the lowest volcanic layer (T1) recognized in the whole Bagua section (Si 84–2, T–Bag.1).

II Radiometric Data (M. Bonhomme)

The Sambimera Member of the Bagua Formation contains intercalations of slightly reworked volcanic silicic tuffs. Four of them were sampled (see location of tuffs T1, T2, T3 and T4 in Fig. 2). Samples from T1, T2 and T4 show weathering of feldspars and were discarted for K-Ar dating. Two samples of T3 (Si 84–4 and Be 84–11) were recollected from the same place at Cerro Fila Larga (5°42′ S and 78°33′ W, see Fig. 3). They have been dated by the conventional K-Ar method. The radiochronological data are presented in Table 1.

Argon extraction-purification was performed using the GI-O international standard sample (Odin 1982) whose value is 24.80 nl/g. The value obtained with this standard for 11 essays is 24.93 ± 0.20 (1 σ).

Table 1 Radiochronological data for the volcanic tuff T3, Bagua basin.
Pl: Plagioclase; Pl-I, Pl-II, Pl-III are three fractions of plagioclases obtained from sample Si 84–4; (a) (b) repetitions on a fraction.
K20 of sample Si 84–4 was determined in Lab. de Spectrochimie of Bondy, ORSTOM. All others analyses were performed in Lab. de Géochronologie, UA 69 CNRS, Grenoble.

Sample N°	Analysed Fraction	K20 %	$\frac{^{40}Ar_{rad}}{^{40}Ar_{Tot}}$ %	$^{40}Ar_{rad}$ (nl/g)	t (Ma ± 1 σ)	
Si 84–4	Pl–I	0.412	74.6 71.1	0.756 0.788	56.0 ± 3.0 (a) 58.3 ± 4.4 (b)	
	Pl–II Pl–III	0.391 0.400	75.9 71.0 74.7	0.876 0.879 0.854	68.1 ± 4.6 (a) 66.8 ± 8.1 (a) 65.0 ± 4.0 (b)	Mean value 66.0 ± 1.6 (1 σ)
Be 84–11	Pl	0.350	88.7 90.5	0.577 0.618	53.6 ± 3.1 (a) 57.3 ± 3.9 (b)	

Discussion

Microscope examination of fractions P1–II and P1–III of sample Si 84–4 show that they contain only fresh plagioclases. In contrast, fraction P1–I of sample Si 84–4 and sample Be 84–11 (P1) contain aproximately 10% of volcanic aggregated glass grains. As glass is known to be a very bad geochronometer because of its high propension to recrystallize even at low temperature, only the ages of the samples Si 84–4 (P1–II) and Si 84–4 (P1–III) must be regarded as valid. Then, the age of the tuff Si 84–4 is 66.0 ± 1.6 M.a. (1 σ) if we consider the mean value of the dates obtained for P1–II and P1–III.

III Paleontology

A) Celendin Formation

1. Ammonites (P. BENGTSON)

Two ammonite zones were previously recognized within the Celendin Formation by BENAVIDES-CÁCERES (1956), the *Buchiceras bilobatum* Zone and the *Lenticeras baltai* Zone, and presumed to be of Coniacian and early Santonian age, respectively. This dating has been generally accepted up to now (e.g., WILSON 1963, COBBING et al. 1981, JANJOU et al. 1981, MOURIER et al. 1986).

According to BENAVIDES-CÁCERES (1956), the *Buchiceras bilobatum* Zone contains ammonites of the genera *Barroisiceras, Solgerites, Forresteria, Tissotia, Heterotissotia,* and *Buchiceras*, i.e., a typical early Coniacian assemblage. The overlying *Lenticeras baltai* Zone contains *Bostrychoceras, Desmophyllites, Texanites, Tissotia,* and *Lenticeras,* which places it most probably in the early Santonian. The ammonites described by RIVERA (1949) from the upper part of the Pongo de Rentema sequence (*Pachydiscus* (*Parapachydiscus*) aff. *P.* (*P.*) *gardneri, Texanites* aff. *T. bourgeoisi, Tissotia singewaldi* and *Lenticeras baltai*) probably belong to the *Lenticeras baltai* Zone. Other records in the literature are not sufficiently precise to determine the zonal affinity.

Conflicting stratigraphical data were presented by RIVERA (1956), who described ammonites from Pongo de Rentema and referred them to the Maastrichtian genera *Coahuilites* and *Paciceras*. She correlated the sequence with the uppermost Cretaceous of the Paita region in northwestern Peru (OLSSON 1944).

MOURIER et al. (1986, p. 173) referred to some of the ammonite specimens studied here as *Tissotia* sp., *Lenticeras* sp. and *Pachiceras* [SIC] sp. and suggested preliminarily a late Coniacian to early Santonian age.

Material

The material for this study consists of 40 specimens from the following localities: Fundo El Triunfo (FET; 30 specimens), Morerilla (MO; 5 specimens), Pongo de Rentema (PR; 3 specimens), and El Pintor (PINC; 2 specimens). The localities are discussed earlier in the paper and located in Fig. 3.

All the specimens are internal moulds, the majority fragmentary and commonly weathered. Suture lines are clearly visible in nearly all the specimens, although deteriorated by weathering in many cases.

The material from Fundo El Triunfo, Morerilla and El Pintor derives from surface collecting within the uppermost ten meters of limestones and black shales of the Celendin Formation, i.e., near the base of the Bagua Formation. The beds are nearly horizontal, which precludes contamination of material from older levels.

The three specimens from Pongo de Rentema were collected from different levels: specimen PR 1 from the top of the Celendin Formation, specimen PR 2 from approximately 100 m lower in the sequence, and specimen PR 3 from the middle part of the formation (N.B.: these lower levels are not represented in the column, Fig. 2).

As a basis for the study, all the ammonites, with the exception of specimens PR 2 and PR 3, are assumed to represent one biostratigraphic level. This also implies that the Celendin – Bagua boundary is isochronous across the Bagua basin and that no stage or substage boundary falls within the ten metres of sequence collected.

The ammonites have been identified as to genera, which permits a sufficiently precise dating of the sequence. A more thorough account of the ammonites, including systematic descriptions, is in preparation by P. BENGTSON.

Biostratigraphic results

MOURIER et al. (1986, p. 172) reported *Coilopoceras* sp., *Tissotia* sp. and *Buchiceras* sp. from presumably the lower part of the Celendin Formation at Pongo de Rentema. These taxa were taken as evidence of the *Buchiceras bilobatum* Zone. Unfortunately, no ammonites from this zone were available for the present study.

Specimen PR 3 from the middle part of the formation is a *Lenticeras baltai* LISSON, which identifies the *Lenticeras baltai* Zone of BENAVIDES-CÁCERES (1956).

Higher in the sequence, approximately 100 m below the top of the formation, one specimen of *Desmophyllites* was found (PR 2). Although this genus is reported from the *Lenticeras baltai* Zone (BENAVIDES-CÁCERES 1956), it is normally not stratigraphically diagnostic and therefore of little value for dating this level.

The uppermost beds of the formation yielded a rich ammonite assemblage. The common denominator is *Manambolites* sp., which occurs at all four localities studied. This supports the assumption that all the ammonites collected from the top of the formation represent the same biostratigraphical level. This assemblage is dominated by the genera *Manambolites* and *Libycoceras*, the taxonomy and systematic relationships of which are as yet poorly understood. ZABORSKI (1982) gives a middle Campanian to Maastrichtian age for the *Manambolites-Libycoceras* succession in Nigeria. However, the vertical ranges of these two genera in Nigeria do not appear to overlap, as seems to be the case in Peru.

A specimen of *Menabites* s.l. from Fundo El Triunfo (FET 30) and a *Submortoniceras* sp. from El Pintor (PINC 6) are crucial for dating the uppermost beds. *Menabites* s.l. is known primarily from the early and middle Campanian of Madagascar and Zululand, the Gulf Coast and adjacent regions of North America (COLLIGNON 1948, 1969, KLINGER & KENNEDY 1980).

Submortoniceras is more widely spread and has recently been reported from Sierra Nevada del Cocuy in the Eastern Cordillera of northern Colombia (ETAYO-SERNA 1985). The genus is reported from late Santonian to mid-Campanian beds (KLINGER & KENNEDY 1980), but is generally taken as diagnostic of the Campanian (BIRKELUND et al. 1984). Based on the co-occurrence of *Menabites* sp. and *Submortoniceras* sp. with *Manambolites* sp. and *Libycoceras* sp., the uppermost level of the Celendin Formation can thus be inferred to be of middle Campanian age. The typical assemblage of these four ammonite genera defines this level and is here provisionally referred to as the *Menabites-Submortoniceras* Assemblage Zone. Further studies of the fauna are, however, necessary in order to confirm the viability of this zone.

The "Maastrichtian" *Coahuilites whitei*, described by RIVERA (1956) from Pongo de Rentema is a *Manambolites* sp. and most likely derived from the *Menabites-Submortoniceras* Zone. *Paciceras olssoni* RIVERA 1956 is best referred to *Libycoceras*, as also suggested by WRIGHT (in ARKELL et al. 1957) and subsequent workers. This implies that the upper "Senonian" of the Paita region (OLSSON 1944) should also be middle Campanian rather than Maastrichtian as previously suggested.

Also present in the *Menabites-Submortoniceras* Zone are juvenile specimens of *Pachydiscus* sp. They are similar to *Pachydiscus besairiei* BASSE, from the middle Campanian of Madagascar (COLLIGNON 1967), but detailed taxonomic studies are necessary before their possible stratigraphic value can be ascertained.

Based on the available material, the Celendin Formation in the Bagua basin can thus be subdivided biostratigraphically into two ammonite zones, viz.:

Menabites-Submortoniceras Zone	middle Campanian
Lenticeras baltai Zone	early Santonian

The *Buchiceras bilobatum* Zone, which forms the base of the Celendin Formation in the Cajamarca area (BENAVIDES-CÁCERES 1956), may also be present in the Bagua basin, although the indications (MOURIER et al. 1986: 172) need further corroboration.

The early-mid-Campanian was in many regions of the world a time of lowered sea level (see, for example, the curves for the U.S. Western Interior of HANCOCK & KAUFFMAN 1979, Fig. 4; and Nigeria, Niger and Libya of REYMENT 1981, Fig. 13). It is possible that this was caused by an eustatic fall of sea level, although mondial data are somewhat conflicting (MATSUMOTO & in REYMENT & BENGTSON 1986, Fig. 17). Such an eustatic fall must have affected also the east Andean epicontinental area and may have contributed to the terminal Cretaceous regional regression in western South America.

Conclusion

(1) The uppermost part of the Celendin Formation of the Bagua basin contains a *characteristic ammonite assemblage,* here referred to as the *Menabites-Submortoniceras* Assemblage Zone.
(2) The age of the *Menabites-Submortoniceras* Zone is mid-Campanian.
(3) The epicontinental sea withdrew from northwestern Peru in mid- to late Campanian times, possibly as a result of a widespread eustatic fall of sea level.

2. Bivalves and Gastropods (J.Ph. Lefranc)

Representatives of these groups are quite abundant in all the exposure areas of the top of the Celendin Fm. In each locality (Cerro Colorado, Fundo El Triunfo, El Pintor, Morerilla) the material was obtained by surface collecting within the last five to ten meters of the black shales.

The faunal list is given in Table 2. Among the bivalves, *Peruarca pectunculoides, Incanopsis acariformis, Plicatula ferryi, Veniella drui* are known from the mid- to late Campanian Tortuga/La Mesa Formations (Amotape and Paita region, NW coast of Peru (Olsson 1944). *Trigonarca angolensis* and *Fragum perobliquum* are known from rather unprecise Senonian

Table 2. Bivalves and gastropods from the uppermost Celendin formation levels, Bagua basin, Peru, and their known occurrence.

	PERU Amotape & Paita regions	U.S.A. Ripley formation	S. AFRICA Gabon, Congo Angola, etc.	N. AFRICA Egypt. Desert Algeria, etc.	EUROPE Germany, France, etc.
BIVALVES					
Arca sp.	–	–	–	–	–
Periarca pectunculoides Olsson	X	–	–	–	–
Trigonarca angolensis Rennie	–	–	X	–	–
Incanopsis acariformis Olsson	X	–	–	–	–
Inoceramus (Catacer.) cf. *goldfussianus* D'Orbigny	–	–	?	?	X
Fragum perobliquum (von Koenen)	–	–	X	–	–
Plicatula ferryi Coquand	X	–	X	X	–
Ostrea sp.	–	–	–	–	–
Astarte sp. aff. *A. subsimilis* Joh. Boehm	–	–	–	X	X
Lucina cf. *angolensis* Rennie	–	–	X	?	–
Isocardia sp.	–	–	–	–	–
Flaventia sp.	–	–	–	–	–
Veniella drui (Munier-Chalmas)	X	–	X	X	–
GASTROPODS					
Proconulus n. sp.	–	–	–	–	–
Calliomphalus cf. *americanus* Wade	–	X	–	–	–
Damesia n. sp. 1	–	–	–	–	–
Damesia n. sp. 2	–	–	–	–	–
Turritella trilira Conrad	–	X	–	X	–
Turritella cf. *saposa* Olsson	X	–	–	–	–
Strombus cf. *tortugensis* Olsson	X	–	–	–	–
Harpagodes n. sp. 1	–	–	–	–	–
Harpagodes n. sp. 2	–	–	–	–	–
Anchura ? cf. *A. pacifica* Olsson	X	–	–	–	–
Cancellaria n. sp.	–	–	–	–	–
Cryptorhytis cf. *bleicherie* (Thomas & Peron)	X	–	X	X	–
Cryptorhytis cheyennesis (Meek & Haydn)	–	X	–	–	–

deposits of Gabon, Congo, Angola, Cameroun. *Veniella drui* (syn. *V. undata*) is recorded from late Campanian to early Maastrichtian rocks in Tunisia, Sahara, Libyan desert, Mali, Nigeria, where it is often associated with *Libycoceras ismaeli* (QUAAS 1901). Among the gastropods, *Calliomphalus americanus, Turritella trilira, Cryptorhytis cheyennensis* are reported in North America from the Campanian – Maastrichstian Ripley Fm. of Virginia, Alabama, Mississippi (SOHL 1960). *Turritella saposa, Strombus tortugensis* are known from the Tortuga/La Mesa Formations of NW Peru.

The biostratigraphic indication given by the bivalves and gastropods for the top of the Celendin Fm., Bagua basin, is a mid-Campanian to early Maastrichtian age. In this regard the most significant fossils are some of the bivalves.

All these molluscs show a rather low degree of endemism. Main faunal affinities (Table 2) are first with the bivalves and gastropods from Amotape and Paita region, NW Peru. Mainly from the bivalves, close relations appear between the Bagua fauna and late Campanian to early Maastrichtian faunas from NE and SW-Central Africa. Less important relations exist with North-American and European faunas.

The ecological conditions suggested are those of an epicontinental marine basin with muddy, finely detritic environments, and quiet, warm to mild, moderatly deep (about 50 m) water.

3. Echinoderms (J. REY)

One tiny specimen, an internal mold of a spatangoid echinid, is recorded from Fundo El Triunfo locality. The major elements for determination (fascioles, apical plates, unpaired ambulacrum) cannot be seen, and the peristome is distorted. According to the general shape, the fossil could be a *Periaster* representative or, less probably, a *Hemiaster* (*Mecaster*) one. No specific attribution can be made, and no biostratigraphic indication is available.

4. Bryozoans (E. BUGE)

An anascan cheilostome bryozoan which incrustates an internal mold of a bivalve was found at Cerro Colorado locality (specimen CC2). It belongs to the *Membranipora* genus and could relate to a new species. No biostratigraphical indication is available from this specimen, for the genus ranges from Early Cretaceous to Recent. Its geographic distribution in Recent extends world-wide, under all latitudes and quite varied depths. The Cheilostomata chiefly withstand normal salinities, but the *Membranipora* genus has the peculiarity to display a large adaptive spectrum, from low to high concentrations.

5. Foraminifera (M. MOULLADE)

The black shales of the top of the Celendin Formation were sampled at Fundo El Triunfo locality. Several samples provided a rather poor and badly preserved foraminiferal microfauna: the state of preservation does not allow taxonomic identification beyond the generic level.

This microfauna consists of 99,9% of benthic foraminifera, and appears to be oligospecific, with an abnormal low diversity. Only one pyritized internal mold specimen, belonging to the subfamily Hedbergellinae, documents the planktonic foraminifera.

Among the benthic forms are found rare foraminifera with agglutinated test (Trochamminidae). Most of the fauna is composed of calcareous tests and is mainly represented by Nodosariidae, belonging to the *Lenticulina, Astacolus,* and *Marginulina* genera.

This depauperate assemblage does not indicate a more refined age than Cretaceous (rather Middle to Late).

The initial environment was clearly marine, but a difficulty lies in attributing the composition of the assemblage either to the original conditions, or to a diagenetic process. For instance, we cannot discern whether the quite lack of the planktonics indicates shallow waters, poorly connected with the open sea or results from a selective dissolution, due to diagenetic conditions. According to the general context, a working hypothesis would more likely imply an internal, shallow, and almost confined environment.

6. Selachians (H. CAPPETTA)

A small selachian fauna was recovered from the last levels of the Celendin Fm. at Fundo El Triunfo locality. It was obtained by screening a sample of the black shales, and also by acetic dissolution of a limestone nodule including large invertebrates and bony fragments (such nodules aggregating invertebrates occur within the shales). The fauna consists in few very small sized selachian teeth, preserved together with some actinopterygian remains (mainly vertebrae). The faunal list is as follows:

– Triakidae nov. gen.

Two complete teeth document this form. Two other different undescribed species of the same genus also occur in South Morocco, the one in the late Campanian, the other in the early Maastrichtian.

– Sclerorhynchidae

This family is represented by rostral and oral teeth. The morphology of the oral teeth does not correspond to that of already known species from North America, Europe, and Africa.

– *Ischyrhiza* or *Dalpiazia*

Only the basal part of a rostral tooth peduncle is available; in the lack of cap, whose morphology is decisive for generic assignment, it is difficult to conclude. The *Ischyrhiza* genus is already reported, by a quite different species, from Maastrichtian deposits of Bolivia (CAPPETTA 1975), whereas *Dalpiazia* has not been pointed out in South America.

– Sclerorhynchidae genus indet. 1

The material is one oral tooth with a non-cuspidate but strongly labio-lingualy flattened crown, with an high and sharp transverse crest.

– Neoselachian inc. sed.

This form is recorded from a single uncomplete tooth which has a triangular, sharp, very flattened crown; the root is worn.

– Orectolobiforme cf. *Chilocyllium*

An uncomplete but characteristic tooth was found.

This small selachian fauna clearly indicates a late Campanian to early Maastrichtian Cretaceous age for the top of the Celendin Fm. Faunal affinities with Africa, as well as some endemism extent, are suggested.

7. Biostratigraphy and paleoecology

Among the different groups of organisms represented in the uppermost strata of the Celendin Formation, the ammonites, the other molluscs and the selachians provide relatively precise and consistent biostratigraphic information. The selachian fishes suggest a late Campanian – early Maastrichtian age. On the basis of bivaves and gastropods the age of these strata would be bracketed between the mid-Campanian and the Maastrichtian. The association of the ammonites *Manambolites* sp., *Libycoceras* sp., *Pachydiscus* sp., *Menabites* sp. and *Submortoniceras* sp. and particularly the two last genera, more precisely indicates a mid-Campanian age. The Foraminifera bear only evidence of a Cretaceous age. The other groups are not in contradiction. So, a mid-Campanian age can reasonably be assumed for the uppermost black shale deposits of the Celendin Formation. This age corresponds to a period of sea level fall in many parts of the world.

The paleoecological conditions suggested by the fauna and particularly the bivalves, gastropods, and Foraminifera, are those of a relatively restricted marine basin with quiet warm to mild shallow waters, about 50 m depth, in which muddy and slightly clastic sediments deposited. Carbonates precipitated in the form of nodules, clustering fragments of invertebrate and vertebrate animals. The impression of confinement given for this environment seems to be – at least partly – attributable to a diagenetic process, responsible for the secondary mineralisation of pyrite, sulfur and gypsum.

B) Bagua Formation

1. Selachians (H. CAPPETTA)

Faunules of small sized selachian teeth were obtained by screening from different localities were basal redbeds are exposed (Pongo de Rentema, T-Bagua, Morerilla). There, these selachian remains are associated with more or less abundant fragments of large reptile bones, wood, eggshell fragments, and charophyte oogones. The selachian list is as follows:

– *Pucabatis* cf. *hoffstetteri* (Pongo de Rentema)

Several teeth have a crown design identical with that of *P. hoffstetteri*, but the size is smaller. These specimens could be either juvenile or ancestral representatives of this species, the type specimen of which is described from the Maastrichtian of Bolivia (CAPPETTA 1975).

– Triakidae nov. gen. (T-Bagua)

One tooth is identical with those recorded from the top of the Celendin Fm.

– Sclerorhynchidae

Genus indet. 1 (T-Bagua)

Two oral teeth are identical with the one recorded from the top of the Celendin Fm.

Genus indet. 2 (T-Bagua, Morerilla)

One oral tooth from T-Bagua locality, medio-distally elongated, cuspidate, with a long transverse crest, differs from all already described forms from North-America, Europe, and Africa. From Morerilla locality was obtained one uncomplete oral tooth.

– Neoselachian inc. sed. (T-Bagua)

One tooth is identical with the one from the top of the Celendin Fm.; the specimen from T-Bagua locality has a more complete root.

– Lamnidae (T-Bagua)

Small eroded crowns were recognized; they do not allow a more precise assignment.

The selachian fauna obtained from the basal redbeds gives two important indications:

1. When the deposition of the redbed sediments began in the Bagua basin area, the conditions still remained marine. An important terrestrial or fresh-water fossil material was carried down to the sea where it was mixed together with marine fish remains.
2. Three selachian species from the basal redbeds are identical with species recorded from the top of the Celendin Fm., i.e. some 15–20 meters below, in the same geographical area. This strongly favors a minor difference in age between both.

2. Reptilian bone remains (PH. TAQUET)

Bone remains are present, scattered, in all the investigated exposure areas of the basal Bagua redbeds. More important concentrations can be found, for instance in the small gullies on the E side of Morerilla locality, in which bones brought out by erosion occur in abundance. These elements are generally fragmentary and weathered, quickly desintegrating, and so complete bones or at least well preserved articular parts are rare, as well as small bones.

Probable pelomedusid chelonians are represented at Morerilla by dermic bone remains (specimen MO–CR 3).

A small sized undetermined reptile is documented by a fragmentary jaw from the same locality (MO–CR 6).

Although new dinosaurian remains, such as vertebrae, have been discovered at Morerilla, no more significant fossil than those previously reported has been obtained.

Titanosaurine dinosaurs seem to be relatively common elements in the assemblages provided by the basal Bagua redbeds. The most characteristic document remains the set of four joint caudal vertebrae found by Th. Mourier at Pongo de Rentema. One of them has been described and figured (in Mourier et al. 1986). The subfamily Titanosaurinae is known from Cretaceous deposits, mainly Upper Cretaceous, in the main continents. According to the moderate size, the affinities of the titanosaurine from the basal Bagua Formation are close to the varied forms described from South America, mainly the Campanian – Maastrichtian deposits of Patagonia (Bonaparte 1978).

A small theropod dinosaur is documented by phalanges fragments and one isolated tooth both recovered from a small exposure area at Fundo El Triunfo; these could belong to the same individual.

3. Eggshell material (K.F. Hirsch)

A small amount of eggshell and eggshell-like fragments have been found at the localities Pongo de Rentema, El Pintor, Fundo El Triunfo, and Morerilla. Their distributions are listed in Table 3. Of these 32 fragments there are three new types of shell structure referred to here as: (1) large mammillae; (2) vermiculate; and (3) thick-gecko-like. Two other types have an avian-like structure which has been previously described (Jensen 1966, Kerourio & Sigé 1984). Four questionable eggshell-like specimens, and one cavity filling were also examined. This material will be described in detail in a later publication.

The questionable specimens are too small and too few to be studied in detail. Two of them resemble somewhat thin gecko-like structure as reported by Sahni et al. (1984) from the Upper Cretaceous of India and Hirsch et al. (1987b) from the Eocene of Wyoming. The other two specimens resemble scutes. Their outer surface is perforated by fairly large (0.13 – 0.25 mm) and closely spaced holes. However, these specimens are composed of calcium carbonate and their microstructure is somewhat eggshell-like.

– Large mammillae type. The striking feature of this new shell type is the high relief of the sculpturing on the outer and inner surface of the shell leaving a relatively thin continuous shell layer. The mammillary, the outer sculptured, and the continuous layer each make up about 1/3 of the shell on the average. The wide range of thickness for this type (Table 3) is probably due to a difference in weathering or erosion in the different localities.

– Vermicular type. The outer surface of this new shell type consists of vermiculate ridges with deep irregular depressions between them. Many of these depressions penetrate the shell in an oblique course to the inner surface, disrupting the crystalline shell layer in such a way that a continuous shell layer cannot be observed under the scanning electron microscope or in radial thin section. The inner surface of the shell is relatively smooth, without mammillary knobs. Columnar faces studded with small crystals such as those found in hatched gecko eggs were observed.

– Thick-gecko-like type. The outer surface of this new shell type is irregularly covered with low, granular nodes. The continuous layer which comprises 3/4 of the shell thickness, has a tight structure, and shows a pronounced herring-bone fracture under the scanning electron microscope. The extinction pattern under polarized light is avian-like. The inner 1/4

Table 3. Eggshell material from the basal Bagua formation, Peru.

Eggshell type and shell thickness	Fragments represented at locality:				Remarks
	Pongo de Rentema	El Pintor	Fundo el Triunfo	Morerilla	
Large mammillae 0.76–1.44 mm	2	3	12	4	
Vermiculate 10.9–1.19 mm	–	–		2	
Thick gecko-like 0.82–1.14 mm	–	–		2	
Avian-like 0.64 mm	–	–	1	–	Jensen 1966
Avian-like 0.51–0.56 mm	–	–	2	–	Kerourio & Sige 1984
Questionable					
? Shell	1	–	1	–	
Thin-gecko-like 0.13–0.23 mm	2	–	–	–	
Others					
Cavity filling 0.58 mm	–	–	1	–	

of the shell, the mammillary layer, has a gecko-like structure. The inner surface of the shell has dimples, each with a pore opening in their center, such as are found in some gecko eggshell.

Discussion. To interpret or classify these new eggshell types, especially with so few specimens, is almost impossible. In the Mesozoic there are many extinct egg-laying species, and we have discovered many new structural eggshell types for which we have no modern counterparts. In addition, the eggs of some of the extinct animals may have had a modern-type eggshell structure, as shown by the avian-like hypsilophodont eggs found in the Upper Cretaceous of Montana.

The new types reported above from the Bagua basin are unique. However, those types with gecko-like features have peculiar features similar to certain eggshells from the Upper Cretaceous North Horn and Lance Formation of the Western Interior (Hirsch 1986, Hirsch et al. 1987a). Gecko eggshell in some cases is strengthened by an outer fibrous layer or fibrous matter which fills gaps between the open crystalline material. This has also been observed in the *Sphenodon* eggshell in which the poorly organized calcareous material is strengthened by the interweaving of fibrous organic matter (Packard et al. 1982).

Only relatively few gecko-like eggshells have been found at any one place in either the Bagua basin or in the Upper Cretaceous of the Western Interior. The scarcity and fragmented nature of the Bagua material strongly suggests that these were not nesting sites. The shell material has probably been transported in some manner.

The specimens from the Bagua basin may be dinosaurian eggshell which is gecko-like in its structure or at least has some features of this type. However, with eggshell from extinct animals, positive identification must be based only on embryonic or hatchling bones (HIRSCH 1986, HIRSCH et al. 1987a). The best identification possible for fragmented and associated material is through comparison with modern eggshell or established fossil eggshell types. Structural types should not be used in classification.

4. Mammals (J.-Y. CROCHET & B. SIGÉ)

In several localities (Pongo de Rentema, Cerro Colorado, T-Bagua, El Pintor, Morerilla), sediments from the vertebrates bearing levels of the basal redbeds were sampled, screen-washed and sorted. None of these samples gave new mammal remains. The tooth fragment which was described, figured and commented as Theria, sp. indet. in MOURIER et al. 1986 represents the only available information for the Upper Cretaceous of the Bagua basin. The lowermost redbeds deposits were formerly postulated to be late Santonian – Campanian in age. The mid-Campanian to early Maastrichtian age now assumed for these same beds seems more consistent with regards to the alleged therian nature of the specimen (placental or more likely marsupial) and its rather large size.

The layer where the specimen comes from is a relatively hard and coarse microconglomerate deposit. It forms a prominent bed of the so-called El Pintor exposure area at about 15 m above the Celendin Fm. – Bagua Fm. boundary.

In all the exposures investigated, the scarcity of small bones and the generally dissociated, fragmentary and worn state of large bones reveal difficult conditions for mammal findings. Nevertheless, in the Bagua region, one cannot exclude the possibility of better areas where land microvertebrates would have been accumulated in channels. So, more detailed prospections remain to be done, as well as investigations in less accessible outcrops.

5. Ostracods (Y. TAMBAREAU)

The population of Ostracoda from Cerro Portachuelo (sample 2730a) includes numerous adults of both sexes and juvenile instars of one single undescribed species. Because of its subrectangular shape with a straight posterior margin, its sexual dimorphism and those of its internal features which have been seen, this species seems to belong to a genus closely similar if not identical to *Neocyprideis* APOSTOLESCU. This euryhaline genus typifies the brackish environment ranging from the Late Cretaceous to Pliocene. The exclusive occurrence of *Neocyprideis*? sp. and its pitted or finely reticulate ornamentation (only one with five phenotypic tubercles) indicate a shallow confined environment, probably a lake with waters salinities reaching the mesohaline domain.

6. Fossil woods (D. PONS)

In different localities, rather large fragments of fossil wood were found by surface collecting at the extreme base of the redbeds.

The Morerilla locality provided two specimens briefly described hereafter. The first one is characterized by: (1) typical medium sized vessels, solitary or in radial groups of 2–3 (5); (2) abundant apotracheal parenchyma in broken uniseriate tangential lines; (3) heterogeneous rays of two distinct sizes, the one short, 1–2 seriate, the another relatively narrow, high multiseriate. Vertical parenchyma is not noticeably storied and crystals are present in chambered cells. The 1–2 seriate rays are more or less storied, and multiseriate (2–5 seriate) range in height from 100 µm to 1,6 mm (mean value : 1 mm). They contain both procumbent and upright cells intermugled with short, squared, or vertically elongated and occasionally crystalliferous cells similar to the tile cells observed in *Hampea* Schlechtd., *Montezuma* Dc. or *Ochroma* Sw. (Bombacaceae) or in *Pterospermum* Scheb. (Sterculiaceae). This wood is clearly related to South American Malvales, known with certainty since Paleocene times.

The second wood from Morerilla resembles the structure of the Lecythidaceae, especially that of the Lecythidoidae subfamily. Vessels are solitary or in radial groups of 2–3, few in number, often large with abundant tyloses. Intervascular pits are medium to large sized. Vertical parenchyma is apotracheal, in uniseriate or rarely biseriate tangential lines and occasionally crystalliferous. Rays are 1–3 seriate, homogeneous, without uniseriate margins and may contain silica bodies. Relationships to the extant *Couratari* Aubl. and *Cariniana* Casar. are suggested. These genera live in lowland neotropical forests with abundant rainfall, superior to 1500 mm per year with none to three drier months. These are slender (leptocaul) canopy trees up to 30 to 45 m high. They prefer well drained sites with rich soils where they can form mycorhizal associations (Prance & Mori 1979). Some species are adapted to wet habitats.

There are fewer fossils records of Lecythidaceae in the New World, and they are mostly Tertiary in age (Prance & Mori 1979, Pons 1983). Nevertheless Milanez (1935) mentioned a fossil trunk, *Lecythioxylon brasiliensis* from the Brazilian Píauí Cretaceous, and Huertas (1969) reported a fruit of *Eschweilera, Lecithydopyxion girardotanum* from the Campanian – Maastrichtian of the Eastern Cordillera of Colombia.

The two silicified woods from El Pintor locality belong both to the Lecythidoidae subfamily. The first one can be attributed to the *Couratari – Cariniana* genera, like the previous specimen. The other is related to the genus *Couroupita* Aubl., common in the upper strata of the lowland tropical forest. The wood of *Couroupita* is easily identified by the absence of silica bodies in the vertical parenchyma, and rays often prolongated with uniseriate margins.

All the studied woods have very weakly defined growth rings, scarcely marked by a line of parenchyma cells slightly more rectilinear at the end of each growth cycle. This suggests a hot climate, regular rainfall with, nevertheless, one drier season.

This short review confirms the existence of Lecythidoidae in South America during the Late Cretaceous, and demonstrates the old origin of the Malvales. Furthermore, the presence of tile cells in the Malvalian specimen establishes that some characters, considered as highly advanced by anatomists studying extant woods, have existed for a long time. This was formerly noticed by Manchester & Miller (1978) and Manchester (1986) within a wood specimen of Sterculiaceae from the Eocene of Oregon.

The high percentage of wood attributed to the Lecythidaceae (3 on 4) is noticeable. This suggests a convergence of favorable circumstances for preservation, but we must recall that this family and the Leguminosae family are both well represented in the extant flora of neotropical lowland rain forests. Perhaps the Late Cretaceous forests of South America had a similar composition.

7. Charophytes (M. FEIST)

a) Pongo de Rentema and Fundo El Triunfo

In these two localities, the basal redbeds contain the same flora, composed of three species. Charophytes of the same association were found too in Morerilla basal redbeds.

– *Amblyochara peruviana* GRAMBAST 1967

This species was described from material found with the first mesozoic mammal discovered in South America, at Laguna Umayo (= Sillustani), Southern Peru (GRAMBAST et al. 1967). This locality was attributed to the Upper Cretaceous on the basis of the charophyte flora, in particular according to the extension of the genera *Amblyochara* and *Porochara*. These genera were later reported from the basal Tertiary (FEIST et al. 1979). This fact is insufficient to question the original Late Cretaceous datation of *A. peruviana*, without directly opposing evidence. Furthermore, in the presently known localities of northern Peru, the species associated with *A. peruviana* support the Upper Cretaceous age.

– *Amblyochara begudiana* GRAMBAST 1962

Until now this species has been reported only from Upper Cretaceous (Maastrichtian) localities of southern France.

– *Porochara costata* n. comb. = *Porochara gildemeisteri* ssp. *costata* KOCH & BLISSENBACH 1960

This species occurs in the flora of the Ucayali Red Beds, studied by KOCH & BLISSENBACH (1960). These authors, and later MÉGARD (1973) considered the Sol 1 Formation, which is the type-level of *P. costata*, as Upper Cretaceous. Additionally this species occurs in several Peruvian localities, attributed by GRAMBAST (unpublished data) to the Upper Cretaceous on the basis of associated species, such as *Amblyochara rolli* (KOCH & BLISSENBACH) and *Saportanella* gr. *maslovi* GRAMBAST.

The Paleocene assignment (RIVERA 1961, GUTIERREZ-CHAVEZ 1975) of the Sol 1 and Arenisca de Azucar Formations, containing *A. rolli* and representatives of *Saportanella*, is not considered here for lack of further evidence.

– Age indication

On the basis of the currently known range of the represented species, the basal redbeds in Pongo de Rentema and Fundo El Triunfo localities appear to be Late Cretaceous, more likely Maastrichtian in age. However, for reasons of general scarce information on Coniacian – Campanian charophytes, and poor knowledge of the lower extension of these taxa, an older, mid- to late Campanian age could not be excluded.

b) Cerro Portachuelo

This locality contains the three following species:

– *Nitellopsis (Tectochara) supraplana* (PECK & REKER 1947) GRAMBAST & SOULIÉ-MÄRSCHE 1972, ssp. A (n. ssp.)

Specific attribution: specimens from this locality clearly correspond to *N.* (*T.*) *supraplana* in their large, ovoid gyrogonites with truncated apex, the weak development of narrowing of spirals and apical nodules, as well as the rather thick basal plate (thicker than in most *Nitellopis* species). They differ from the subspecies *supraplana* and *costata* by their slightly smaller size.

Distribution: Although this subspecies has not been published, it has been used for dating in several geological studies of Peru. For example. *N.* (*T.*) *supraplana* ssp. A is one of the Eocene species found in the Nuñoa area (Southeastern Peruvian Andes) near the base of the Muñani Formation (AUDEBAUD et al. 1976). These Nuñoa specimens (AUDEBAUD Z787. 42/2 and 43a/2) were studied by L. GRAMBAST and are housed at Montpellier (U.S.T.L. collections).

Range of *N.* (*T.*) *supraplana*: PECK (in GRAMBAST 1962) considers the type-locality Contamana (Loreto, Peru) as Eocene. In Ucayali, this species occurs in the upper part of the Sol 3 Formation (KOCH & BLISSENBACH 1960), now placed in the Tertiary, Paleocene or Lower Eocene (MÉGARD 1973).

Range of *Nitellopsis*: Dano – Montian to Recent.

– *Maedleriella* sp. B (n. sp.)

Gyrogonite subglobular with spirals ornamented by a median line, either continuous or subdivided in thin tubercles; gyrogonite diameter varying from 430 to 530 µm. As this particular form cannot be assigned to any described species, only the genus range of *Maedleriella*, from Maastrichtian to Bartonian, may be used for dating.

– "*Chara strobilocarpa* REID & GROVES"

Gyrogonites cylindrical, with high number (10–13) of convolutions, apex obtuse and base tapered; size varying from 650 to 950 µm in length and 500 to 700 µm in width. This species, also represented in Contamana (see above), is referred to *Chara strobilocarpa* by PECK & REKER (1947). They indicate, however, that the Peruvian specimens differ appreciably in shape and size from the type specimens of the Upper Eocene of Hampshire (Great Britain). The Peruvian material must represent a new species, whose description would, however, depart from the present work's aim. Thus, we continue the attribution of the previous authors. Forms very close to the Peruvian one occur in various Asian localities assigned, as in Contamana, to the Paleocene or the Lower Eocene: "*Grambastichara* cf. *subcylindrica* REID & GROVES" for example, cited by WANG et al. (1982) from the Paleocene of Jiangsu (China).

– Age indication

The genus association of *Nitellopsis* and *Maedleriella* indicates the Tertiary and more exactly the Dano – Montain to Bartonian interval. The presence of representatives of *N.* (*T.*) *supra-*

plana as well as of specimens quite similar to the "*Chara strobilocarpa*" indicates a probable correlation with the Lower Tertiary (Paleocene – Eocene) of Eastern Peru.

8. Biostratigraphy, chronology, and paleoecology

Concerning the age of the base of the Bagua Formation (F.E. Triunfo Member), direct and indirect indications are available.

– Direct indications: Titanosaurine dinosaurs are known in South America, particularly in Patagonia, from Campanian and Maastrichtian deposits. Selachian fishes provide the same stratigraphic indication. The assemblage of charophytes with *Amblyochara peruviana, A. begudiana*, and *Porochara costata* characterizes more precisely the Maastrichtian, without definitely excluding an older age.

– Indirect indications: A long chronological gap is unlikely between the last deposits of the Celendin Fm. and the first ones of the Bagua Fm., both fossiliferous. The first redbeds rest conformably on the Celendin Fm., and even show an apparent gradational transition (MOURIER et al. 1986), suggesting that, despite a strong change in paleoenvironment, there was no prolonged break in sedimentation. On the other hand, the two successive levels have in common three species of selachians (Triakidae nov.gen., Sclerorhynchidae gen. indet. 1, and Neoselachian inc.sed.). This indicates an unceasing local evolution of some elements of the marine fauna during a period of time equal and more probably inferior to 5 Ma (commonly accepted life duration of a vertebrate species).

Consequently the age of the lowermost redbeds, F.E. Triunfo Member of the Bagua Fm., with dinosaurs, charophytes, and other organisms, is bracketed between middle Campanian and early Maastrichtian, and is more likely late Campanian.

The marine nature of the environment is warranted by the selachian remains found in most of the exposures. In these shallow and warm marine waters, fine grained clastic sediments deposited, with significative precipitation of carbonates (abundance of algal crusts fragments and concretionary pisoliths reworked in marls and microconglomerates). Remains of land and fresh water organisms were brought and spread in these deposits, certainly by channeled transportation. The fossil woods study (D. PONS, this paper) indicates that the neighbouring continental areas consist in low to medium altitude lands covered with lowland tropical forests. The climate was hot with abundant rainfall almost continuous in spite of a slight seasonal let-up.

The emergence of the Bagua area must have been effective after a still imprecise duration of redbed sedimentation. Only after deposition of F.E. Triunfo Member, the disconformably overlying conglomeratic Rentema Member bears evidence of tectonism related to the Peruvian compression phase. The contemporaneous emergence and Peruvian tectonism, as postulated by most authors, is now questioned. It is more likely that an early – mid-Campanian fall of sea level was, at least in part, responsible for the emergence of this area of the Andes.

A bed of the Sambimera Member, about 200 m above the Celendin – Bagua boundary, yielded a charophyte association with *Nitellopsis* (*Tectochara*) *supraplana, Maedleriella* sp. B, and "*Chara strobilocarpa*" indicating an Early Tertiary age, Dano – Montian to Bartonian (M. FEIST, this paper). The volcanic tuff (T3) interbedded in the Bagua Fm., 50 m above the level with these charophytes, provided the possibility to get several K–Ar data (M. BONHOMME, this paper), indicating for this tuff an age of 66.0 ± 1.6 Ma, close to that of the Cretaceous – Tertiary boundary (ca. 68 Ma). This K–Ar age is not conflicting with the rather large biostratigraphic indication provided by the charophytes but tends to warrant the oldest pole of it. Then the age of the Cerro Portachuelo bed with the second charophyte association could be most probably latest Cretaceous to early Paleocene.

The ostracod fauna from the same bed as the charophytes indicates a shallow confined lacustrine environment, with relatively high salinity.

IV Andean Correlations (B. Sigé, G. Laubacher & P. Bengtson)

The stratigraphic sequence of the Bagua syncline described in this paper makes biostratigraphic and geochronological dating possible, and also enables correlation hypotheses to be put forward involving various Andean and sub-Andean zones in Peru and Bolivia (Fig. 1). These hypotheses are described below and recapitulated in Table 4.

1. Celendin Formation

The molluscan fauna, particularly the bivalves and gastropods (Table 2), confirms Rivera's (1956) correlation of the uppermost Celendin Formation and the Upper Cretaceous Tortuga and La Mesa Formations in the coastal region of Paita (northwestern Peru) studied by Olsson (1944). The ammonite *Paciceras olssoni* Rivera, 1956 is best referred to *Libycoceras*, as also suggested by Wright (in Arkell et al. 1957) and subsequent workers. This implies that the "Senonian" of the Paita region is Campanian rather than Maastrichtian as previously suggested.

The latest Cretaceous ammonites of the Andes are in general poorly known. A recent record of interest, however, is the fauna described from Sierra Nevada del Cocuy in the Eastern Cordillera of Colombia (Etayo-Serna 1985). The stratigraphic column in question consists of ca. 800 m of sediments, referred to the La Luna (Santonian-Campanian), Los Piños (upper? Campanian), and Arenisca Tierna (Maastrichtian) formations. *Submortoniceras* sp. occurs in the upper La Luna Formation (Campanian), associated with *Pseudoschloenbachia* spp. and *Hauericeras* sp. The occurrence of *Submortoniceras* in the upper Celendin Formation of the Bagua Basin suggests contemporaneity, i.e. a Campanian age. However, the associated *Manambolites* and *Libycoceras* pose correlation problems. In Colombia *Libycoceras* co-occurs with *Sphenodiscus* in the basal Arenisca Tierna Formation (lower? Maastrichtian), i.e., at a level apparently several hundred meters above the *Submortoniceras* occurrence. Although the Colombian *Libycoceras-Sphenodiscus* assemblage may be younger than the Peruvian *Libycoceras-Manambolites* fauna, an age difference in the order of a stage duration appears unlikely. An undetected major stratigraphic gap or an inadvertent mixing of specimens at the time of collecting are also unlikely. In the sampled localities only the uppermost part of the Celendin Formation is exposed, the beds are nearly horizontal, and there is no deep valley to account for a mixing of faunas. For the time being, a broad correlation between the upper Celendin beds and the upper La Luna to lower Arenisca Tierna sequence of Colombia is all that is possible.

2. Bagua Formation

Two charophyte combinations which are stratigraphically and systematically distinct were obtained in the lower beds of the Bagua Formation. One is at the base of the F.E. Triunfo Member and the other approximately 200 m higher in the section in the lower part of the Sambinera Member. As previously stated the first level can be attributed to the mid-Campanian – early Maastrichtian interval and more probably to the late Campanian. The second level is likely to be Late Cretaceous – Paleocene, and more probably Early Paleocene. Typical components of these two charophyte combinations are known in other Andean areas:

Ucayali area

In this area (eastern central Peru), *Porochara costata* is a feature of the flora of the Sol 1 Formation considered to belong to the Upper Cretaceous by KOCH & BLISSENBACH (1960). The species *Nitellopsis* (*Tectochara*) *supraplana* characterizes the flora of the Upper Sol 3 Formation, considered by KOCH & BLISSENBACH (o. c.) to be probably Cretaceous, and by MÉGARD (1973) to be Lower Tertiary (Paleocene – Lower Eocene). A double correlation is proposed here between the lower charophyte-bearing Bagua level (F.E. Triunfo Member) and the Sol 1 Formation on the one hand, and between the upper Bagua level (Sambinera Member) and the Upper Sol 3 Formation. It is to be noted that the locus typicus of *Nitellopsis* (*T.*) *supraplana* PECK & RECKER is Contamana (South of Loreto Province, NE Peru) but the various units of the Contamana Formation itself are overlying the stratum typicum of this species (KOCH & BLISSENBACH o.c.).

Southern Peru

Floras including charophytes have been described, reported or are obtained but still unpublished in the Lake Titicaca region in various Upper Cretaceous and Lower Tertiary horizons. The species *Amblyochara peruviana* has been described in the Laguna Umayo (= Sillustani) vertebrate-bearing level where it is found together with *Porochara gildemeisteri* and *Porochara* sp. The Vilquechico Formation near the type locality has been attributed to the Upper Cretaceous since NEWELL (1949) on the basis of a charophyte flora which includes in particular *Porochara ovalis* and *Platychara perlata*. The species *Porochara gildemeisteri* has also been reported in the Arenisca de Azucar Formation (Ucayali) underlying the Sol 1 Formation. It is combined there with *Amblychara rolli* and representatives of the *Saportanella* genus.

In the same southern part of Peru, and particularly in the Nuñoa zone, the species *Nitellopsis* (*Tectochara*) *supraplana* has been identified in the lower part of the Muñani Formation overlying the Vilquechico Formation (AUDEBAUD et al. 1976). A double correlation is proposed again: firstly between the Vilquechico Formation, the base of the Bagua Formation (F.E. Triunfo Member) and the Sol 1 and Arenisca de Azucar Formations (Ucayali) and secondly between the lower part of the Muñani Formation, the lower part of the Sambimera Member of the Bagua Formation and the Upper Sol 3 Formation (Ucayali). In addition to charophytes, it has been observed that the same avian-like eggshell type (K.F. HIRSCH, this paper) is present in the F.E. Triunfo Member of the Bagua Formation and in the Laguna Umayo level (KEROURIO & SIGÉ 1984).

Table 4 Correlations of late Cretaceous and early Tertiary formations of Peru and Bolivia (1: according to BERGGREN et al. 1985).

Ma. (1)	Stratigraphy	BAGUA	PAITA	SAN MIGUEL	LORETO UCAYALI	CUZCO	N TITICACA	SC BOLIVIA
	EOCENE							
60					CONTAMANA Fm			Camargo
	PALEOCENE	SAMBIMERA Mb Tuff 3 ∓				PUNA CANCHA Fm	MUÑANI Fm	SANTA LUCIA Fm
					SOL 3 Fm		Nuñoa	
70	MAASTRICHTIAN	BAGUA Fm RENTEMA Mb		REDBEDS		SONCCO Fm	Huarachani	Tiupampa
								Torotoro
		F.E. ∓ TRIUNFO Mb			SOL1 Fm ARENISCA DE AZUCAR Fm	K'AYRA Fm	Laguna Umayo VILQUECHICO Fm	Managua EL MOLINO Fm
80	CAMPANIAN	∓	TORTUGA Fm LA MESA Fm	— — — —				
		CELENDIN Fm		CELENDIN Fm			COTACUCHO Fm	TARAPAYA Fm
	SANTONIAN							
						YUNCAYPATA Fm		

The black lutite facies which is presumably of marine origin and Late Cretaceous or Paleocene age reported near Huarachani in the Rio Suches zone north of Titicaca (ARGOLLO et al. 1987) may be evidence of a period of marine recurrence to be referred to the upper part of the Vilquechico Formation, as suggested by MARTINEZ (1980: 183).

Central Peru

MÉGARD (1978) proposed an intra-Santonian age for the transition from the Celendin Formation to the redbeds in the high plateaux and in the Eastern Cordillera of central Peru. The change is transitional or slightly discordant depending on the zone. The base of the redbeds is not dated accurately anywhere. Nevertheless, MÉGARD (o.c.) reported the existence near San Miguel of *Porochara gildemeisteri* and *Amblyochara* sp. (determined by L. GRAMBAST) in levels distinctly overlying the base of the redbeds. It would seem that the lower part of the redbeds in this region could be at least partly correlated with the Arenisca de Azucar (Ucayali) and Vilquechico (southern Peru) formations and should be related to the Campanian.

Cuzco region

In this region, the Albo-Turonian marine series (Yuncaypata Formation) changes by transition or discordance to the Late Cretaceous – Eocene continental redbeds (Marocco 1978). Present data are not sufficient to date the emergence with any accuracy. Nevertheless, Cordova (1986) provided important information about the redbeds by proposing that they should be subdivided into three parts: the K'ayra, Soncco and Puna Cancha formations. The presence of *Porochara ovalis* and *Porochara* sp. (determination L. Grambast in Marocco o.c.) in the K'ayra Formation indicates that it is Campano – Maastrichtian, suggesting probable correlation with the Vilquechico Formation further south. The upper part of the Soncco Formation above it contains dinosaur footprints (Cordova, o.c.), supporting the idea that this unit is still Cretaceous. The Puna Cancha Formation is referred to the Paleocene by its stratigraphic position.

Bolivia

In the central southern part of Bolivia, charophyte floras are known from the El Molino and Santa Lucia Formations whose ages are reported as being Early Cretaceous and Late Tertiary respectively. The species *Amblyochara peruviana, Platychara* cf. *perlata* and *Porochara* sp. (Branisa et al. 1969) are known particularly in the El Molino Formation at Managua. This association is closely related to those found in the Vilquechico Formation in the south of Peru. Several other fossils, particularly fish, reptiles and some mammals such as *Peradectes austrinum* (Marshall & De Muizon 1988) are common to the vertebrate fauna deposits at Laguna Umayo, Vilquechico Formation, southern Peru and at Tiupampa, El Molino Formation, south-central Bolivia (de Muizon et al. 1983). In addition, a fauna of selachians (including *Pucapristis branisi, Ischyrhiza hartenbergeri, Dasyatis branisai, D. molinoensis, D. schaefferi* and *Pucabatis hoffstetteri*) considered to be Maastrichtian has been described from the base of the El Molino Formation at Torotoro (Cappetta 1975). The same assemblage has been found in the same formation near Tiupampa in a level slightly lower than that known for mammals (de Muizon et al., o.c.). *Pucabatis* cf. *hoffstetteri* has been identified at the base of the Bagua Formation in the F.E. Triunfo Member where it could represent either a juvenile or an ancestral form of *P. hoffstetteri* (H. Cappetta, this paper). The species *Pucapristis branisi* has also been found in the Vilquechico Formation (Davila & Ponce de Leon 1971).

These data strongly support for the hypothesis of broad correlation between the Peruvian Vilquechico and the Bolivian El Molino formations previously put forward (Martinez 1980, p. 192, de Muizon et al. 1983). Although the precise stratigraphic extent of these formations cannot yet be determined, it is nevertheless reminded that a varied fauna of land vertebrates including large sauropod and theropod dinosaurs (Marshall et al. 1985) is found near the top of typical El Molino Formation at the Torotoro ichnological site; this supports the notion of the Cretaceous age for whole of the El Molino deposits, at least as regards its typical lithological facies.

After examination of the original samples, the charophyte *Chara* sp. reported from the Santa Lucia Formation in the Camargo region south of Potosi (Branisa et al. 1969) is identified here (by M. Feist) as being a representative of *"Tectochara" ucayaliensis oblonga*, whose type is from the Contamana Formation in Ucayali (Koch & Blissenbach o.c.). This new data considerably modifies the stratigraphic evidence previously deduced for this fossil (Middle Eocene to Oligocene) and makes it possible to place the Santa Lucia Formation much earlier (Paleocene – Eocene). This new age seems more consistent with regard to various data connected with this formation : 1) its stratigraphic relation which concords, with no apparent gap, with the underlying El Molino Formation (BRANISA et al., o.c.); 2) its assumed correlation with the Lumbrera Formation, uppermost component of the Santa Barbara sub-group (Puca Group) in NW Argentina (SALFITY 1982), referred to the Patagonian Casamayorian land mammal age (Early Eocene) on the basis of its mammal fauna (PASCUAL et al. 1981); 3) among the other rare paleontological data available to date on the Santa Lucia Formation, the finding at Vela Pachita of a rather primitive notoungulate mammal close to classic Paleocene forms (SIGÉ et al. 1984). So, the fresh information provided by the charophytes suggest a correlation of the Bolivian Santa Lucia Formation with the Contamana Formation (Ucayali, Peru), and possibly at least partly with the Muñani Formation in southern Peru.

Conclusions

The correlating of stratigraphical units recognized for the Upper Cretaceous and Lower Tertiary over a large geographical area involving Peru and Bolivia leads to a consistent overall pattern (Bagua, Ucayali, Titicaca, Bolivia), thanks in particular to a double correlation based on charophytes, with a Campanian – Maastrichtian component and an Early Tertiary one. In turn, this overall coherence backs up the relevance and interest of particular data which, when deliberately considered out of their stratigraphic context, have led to questions. On this point, the case of the vertebrate and charophyte bearing level of Laguna Umayo (southern Peru) can be mentioned; its dating as Late Cretaceous by GRAMBAST et al. (1967) is clearly supported by the present correlations, whereas it is considered of no value by certain recent authors who, judging only from the progressive stage of its *Perutherium* mammal, claimed this deposit to be Tertiary, and cited it as one of the proofs of the duration of dinosaurs beyond the Cretaceous – Tertiary boundary (SLOAN et al. 1986, note 10).

General Conclusions

The fresh stratigraphic, radiometric, paleontologic and biostratigraphic data obtained for the uppermost Celendin Formation and the lower part of the Bagua Formation make it possible to specify the date of the emergence of the Andes in this region, the age of Peruvian tectonics and the position of the Cretaceous – Tertiary boundary.

It is the first time that the transition from Late Cretaceous marine sedimentation to the continental redbeds has been dated so accurately in Peru. Emergence occured during the mid – Campanian to early Maastrichtian whereas it has been assumed up to now (BENAVIDES-CÁCERES 1956, COBBING et al. 1981, JANJOU et al. 1981, MOURIER et al. 1986) to have occurred during the Santonian.

The unconformity of the Rentema Member conglomerate on the F.E. Triunfo Member is the main significant tectonic feature in the Bagua basin. We consider that it belongs to the

Peruvian phase (Steinmann 1929) and date it as late Campanian to Maastrichtian. A time lag is suggested between the depositing of the first layers of the F.E. Triunfo Member, which are earlier than or sub-contemporary to emergence, and the first occurrence of the Peruvian phase. Such a lag would cast doubt on the direct relationship which is generally assumed between the two events. It might be wondered whether emergence may not rather reflect the early and mid-Campanian regression episode observed in some other parts of the world.

The Cretaceous – Tertiary boundary in the Bagua basin sequence necessarily stands at the base of the Bagua Formation in the sedimentary interval following the F.E. Triunfo Member and preceding the tuff dated 66.0 ± 1.6 Ma (M. Bonhomme, this paper) and probably too the thin underlying limestone bed which bears the second charophyte association. This interval, which includes the whole of the Rentema Member and the base of the Sambimera Member, forms approximately 170 metres of the section. The unconformity observed between the F.E. Triunfo and Rentema Members also means that there is a sedimentary gap whose real scale cannot be determined yet but should not be underestimated. If it is assumed that the F.E. Triunfo Member is mid-Campanian to lower Maastrichtian, and the upper bed with charophytes Lower Paleocene, the duration implied by the interval includes the whole or most of that of the Maastrichtian and possibly those of more or less large parts of the late Campanian and the Early Paleocene. The interval covers very roughly 9 to 13 Ma.

Thanks to its paleontological content, the Bagua section thus permits an observation of the Cretaceous – Tertiary boundary among the most precise to date available for the Andean and South American stratigraphy. Checking and further details will probably follow the present results through the dating in progress of volcanic tuffs of the lower part of the Bagua Formation, only one of which (T3) has provided geochronological data untill now. The lithological facies, which are generally coarse, do not at first sight appear to favor the development of a magneto-stratigraphic program in this zone.

Descriptive, systematic work using the paleontological material collected is in progress for various groups of organisms of the Bagua sequence: invertebrates from the Celendin Formation, vertebrates and plants from the Bagua Formation. Further prospection should significantly enrich the fossil record. In particular, the finding of new charophyte floras in levels between or overlying those which are reported does not appear to be unlikely, and would enable considerable biostratigraphical, methodological and correlational refining.

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