

The reconstruction of the paleo-living environment, death and taphonomy of 'Eva' a juvenile titanosaur at the Late Cretaceous site of Bellevue in the Haute Vallée de l'Aude in southwestern France

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Foreword

This small book of only two chapters is intended for geoscientists and a general science audience. The first chapter focuses on presenting the observations and interpretations, at the Late Cretaceous (Maastrichtian) site of Bellevue in the Haute Vallée de l'Aude in southwestern France. The second chapter contains simplified scientific approaches to three complex questions regarding the paleoenvironment of Bellevue.

It has to be emphasised that the material presented here is the result of the first comprehensive study focusing on the site of Bellevue. Therefore, it is clear that the results presented are by no means in their finalised version. My work needs to be advanced and improved by further studies, and further thought is necessary to properly approach the answers to the complex questions I attempt to tackle in chapter two.

Nevertheless, I hope that the reader will enjoy my work, think about it, criticise it, go to sleep with it, and wake up with it...in the Late Cretaceous!

Let the journey begin!

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Abstract. The present study is the first comprehensive analysis performed on the Late Cretaceous site of Bellevue in the Haute Vallée de l'Aude in southwestern France. It presents primary results and is intended to be the foundation for further investigations at the site of Bellevue. The focus of this study is the reconstruction of the paleo-living environment, death and taphonomy of a juvenile titanosaur, known as 'Eva', present at the site. The depositional environment during the Late-Cretaceous in the Haute Vallée de l'Aude was characterised by frequent changes from river channels to floodplains. The strata present at Bellevue bear similarities to three fluvial facies, a braided river, a meandering river system and a crevasse splay deposit. Further, and more geographically extensive studies are required to clarify the exact nature of the sediments. The paleo-climate was warm, most probably a tropical Aw-type climate with distinct wet and dry seasons, resulting in more than 500 mm of annual precipitation. The paleo-ecological setting was found to be very diverse with respect to both flora and fauna. Numerous remains of palms, cycads, crocodiles, pterosaurs, fish, dinosaurs and freshwater invertebrate species (mostly gastropods and mollusks) have been unearthed. The statistically high representation of titanosaur vertebrate remains can be best understood when considering the preferred living environment of sauropod dinosaurs, which was in proximity to rivers. The fossil assemblage at Bellevue is allochthonous with the exception of Eva, whose fossilisation must have taken place either at her place of death or after minimal transport, since the bones of her nearly complete skeleton are very well preserved.

Keywords. France, Maastrichtian, sauropoda, tropical environment, fluvial sediments, taphonomy.

Chapter One

The site of Bellevue

“I have spent seven years of my life on a ship.
I have seen it all; waves as high as
skyscrapers, oceans as smooth as a mirror.
Water has an incredible power, a power over
life and death.
And somehow, everything comes back to it.
Everything comes back to water.”

– Cyril Davies, my beloved father, Able
Seaman.

Introduction

The Haute Vallée de l'Aude is located in the southwestern part of France, in the foothills of the Pyrenees, about 40 kilometres to the south of Carcassonne. In the neighbourhood of three villages, Espérasa, Rennes-le-Château and Campagne-sur-Aude, more than 40 geological and paleontological outcrops can be found. The site of Bellevue is located near the Aude River, about 250 metres towards the northwest of the village of Campagne-sur-Aude. Its IGN-coordinates are as follows: 1/25000 N 2347-west, X=435,05; Y=4752,4; Z (altitude)=330m (Schulp, 1995/1996). Figure 1 contains further geographical information and figure 2 shows the site of Bellevue in its vicinity of Campagne-sur-Aude.

The geology of the Haute Vallée de l'Aude has been studied (Bilotte, 1984/85; Bilotte et al., 1989; Freytet et al., 1982; Groebke, 2001). All of these studies have focused either on structural geology or on cartography and the mapping of the different lithologies found in the region. Despite the fact that sections of these studies incorporate information on invertebrate fossil remains, only few other studies, all of them incomplete and unpublished, or handwritten, focus on the site of Bellevue (Proudhon, 1993/94; Proudhon & Schulp, 1993-96; Schulp, 1996; Le Loeuff & Buffetaut, 1998; Albagli & Lurz, 2002). This is surprising, since the first discovery of Mesozoic floral and vertebrate faunal remains at the late-Cretaceous (Maastrichtian) site of Bellevue dates back to the end of the 19th century (Albagli & Lurz, 2002). However, no work was done there until 1982 when Christian Raynaud and Pierre

Clottes, two teachers at Espéraza, rediscovered the site. The first excavations began in 1989, and have since then been an annual activity. The site of Bellevue has great importance. About 2500 bone remains have been unearthed and prepared in the dinosaur museum at Espéraza (Albagli & Lurz, 2002).

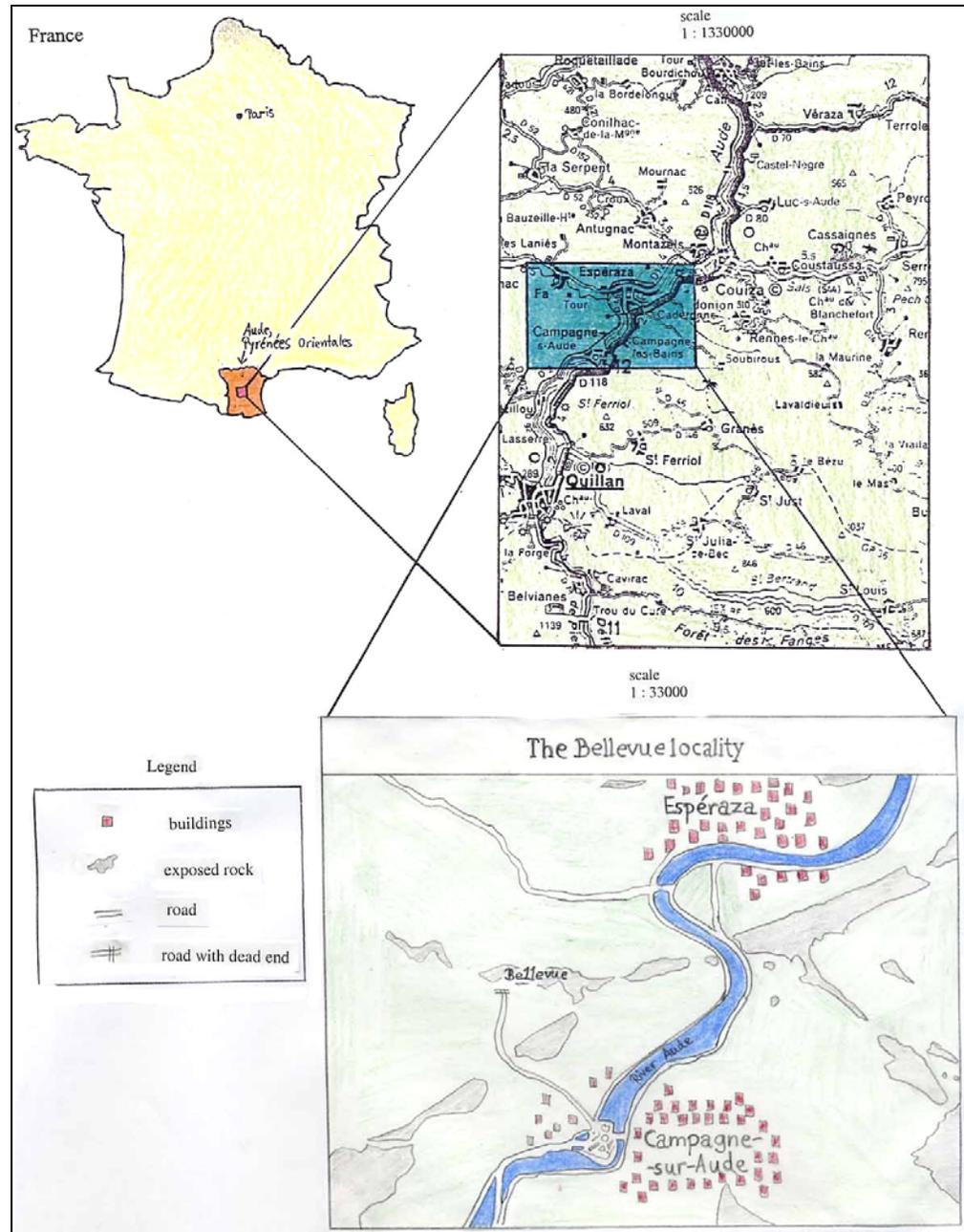


Figure 1: Map showing the geographical location of the site of Bellevue.



Figure 2: A picture of the locality of the site of Bellevue (framed in yellow) and its surrounding area. The village in the front of the picture is Campagne-sur-Aude.

During the course of the excavations at the site of Bellevue in the summer of 2001, a nearly complete skeleton of a juvenile *Ampélosaurus atacis* (titanosaur) was found. The skeleton, known as ‘Eva’, was fully unearthed during the excavations in the summer of 2002 in which I participated (Figure 3).

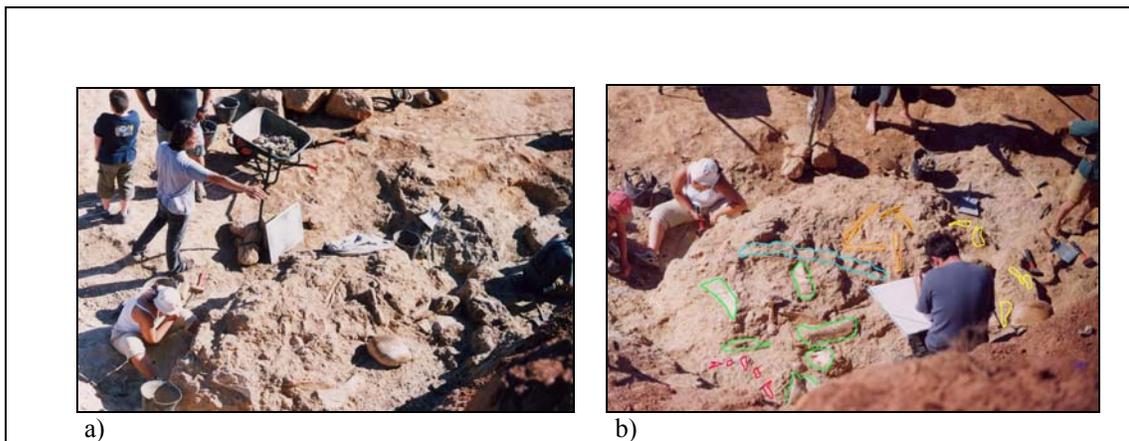


Figure 3: a) Paleontologist Jean Le Loeuff presenting the skeleton of Eva to tourists. b) Outlined parts of Eva’s skeleton; blue: dorsal vertebrates; orange: ribs; yellow: forelimb parts; green: hindlimb parts; red: tail vertebrates.

The present study is the first of its kind, and intends to be a comprehensive foundation for further research at the site of Bellevue. It attempts to do both, to give an overview and interpretation of the field and laboratory results, as well as to present experimental results and hypothetical case studies that are less supported by field data, but not less valuable for gaining a solid understanding of the site of Bellevue and its context. In the first chapter, I give an overview of the sedimentology, mineralogy, climate and taphonomy. In the second chapter I attempt to approach the magnitude of the ancient water force experimentally, resurrect the paleoecology for the fossil assemblage unearthed at the site during the summer of 2002, and present some hypotheses on how the sediments at the outcrop might have formed.

My research at the site of Bellevue suggests the following:

1. The outcrop was once located within a fluvial system, either towards the margins of a braided or a meandering river, or on the floodplain immediately adjacent to the main channel with substantial crevasse splay influence.
2. The climate was hot. Most likely, the region of study pertained to a tropical Aw-type climate zone.
3. The paleoecology was rich and diverse, though the fossil record is dominated by titanosaur remains.
4. The majority of the vertebrate fossil assemblage is allochthonous, with the exception of Eva's skeleton, which is very much in situ or has only undergone minor post mortem transport.

A summary of the geologic formations in the Haute Vallée de l'Aude is listed in Table 1. Figure 4 positions the site of Bellevue and its adjacent formations on the geologic time scale.

Table 1: Summary of the formations in the Haute Vallée de l'Aude. Only the upper two formations contain fossils (mostly soft water mollusks, charophytes and ostracods). As has been shown in the work done by Ina Groebke (2001), the sequence of formations in the Haute Vallée de l'Aude represents a gradual change from fluvial to lacustrine deposits.

The Grès d'Alet (stratigraphically lowest)

- thick series of mainly siliciclastic material
- schist-based pebbles interspersed throughout the formation
- silt-rich marls bear evidence of plants

The Marnes Rouges Inférieures

sub-units:

- Marnes Rouges de Campagne: sandy marls, mostly of ochre or red colour
- Grès des Estous: sandstone formation with remains of dinosaur egg shells
- Marnes Rouges de la Maurine: colourful marls show thorough reworking of paleosols, with conglomerate bodies; very rich in fossil remains of sauropods, theropods and ornithopods
- Poudingue Fleuri: polygenic conglomerate with pebbles and calcareous cement

The Calcaires et Argiles de Vignevieille (stratigraphically highest)

sub-units:

- Calcaire Inférieur de Vignevieille: white, very well compacted limestone
- Argile de Vignevieille: red clay with sandlenses
- Calcaire Supérieur de Vignevieille: marmorised, often nodular limestone

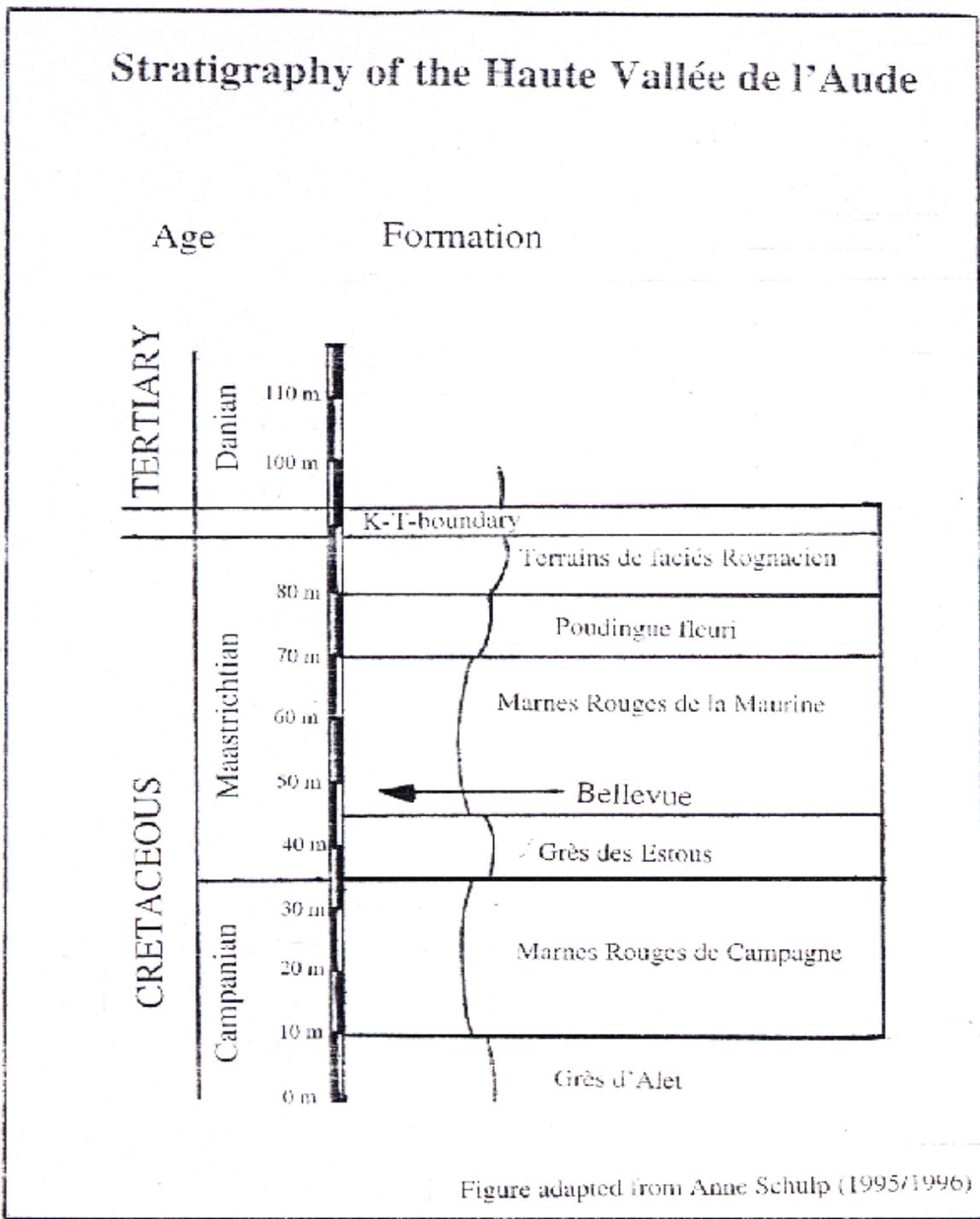


Figure 4: Geological profile showing the stratigraphy of the Haute Vallée de l'Aude.

Methods

During my nearly one month long stay at the site of Bellevue, I made observations (measurements, photography, mapping) regarding the stratigraphy, sedimentology, the mineral assemblage, the preservation status and the orientation of the bones, as well as the paleofloral and paleofaunal composition present at the site. Figure 5 shows the tools available and a picture of the outcrop at the site of Bellevue.

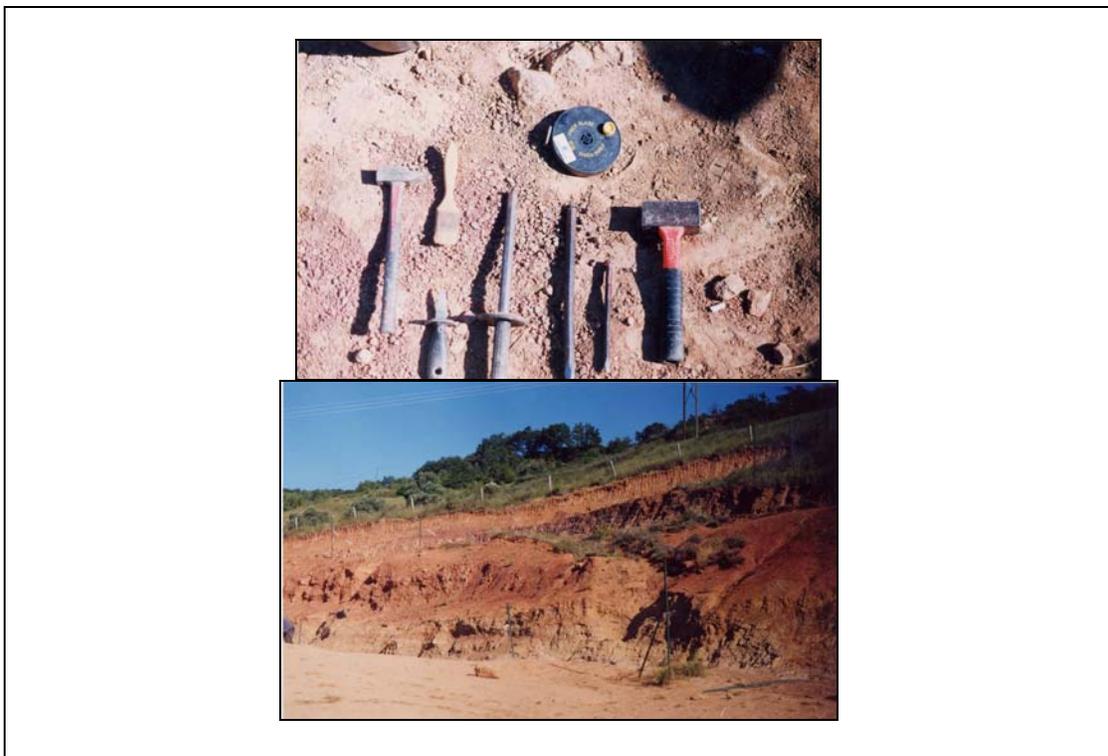


Figure 5: Pictures of the tools available at the site and the outcrop of Bellevue.

In the laboratory 30 thin sections were made in order to conduct a mineralogical study and to change the scale of observation. In the experimental section, weight-based models of Eva, made of different materials, have been constructed and inserted into Spring Creek near Northfield, MN, USA, to obtain the

discharge value at which each of the models tipped over. This approach was taken, because it is likely that the juvenile dinosaur drowned (see section on Eva's death). Experiments for bone and carcass transportation potentials in rivers have been conducted with partially defleshed and largely articulated racoon skeleton parts and a dead squirrel. Calculations based on previous animal physiological and botanical studies have been made for the reconstruction of the paleoecology.

Stratigraphy

Facies and sediment characteristics

The five facies found at the site of Bellevue are listed in table 2.

Table 2: Summary of facies attributes and their interpretation. The Fm, Fm/Fl and Fl facies are marls and constitute the paleosol group. They can hardly be distinguished from each other.

Name and Facies	Lithology	Bioturbation	Fossil remains and taphonomy	Interpretation
Conglomerate Gm	Calclitic conglomerate with and without vertebrate remains; grains (quartz and amorphous silica) mostly rounded with sizes ranging up to 1 cm in diameter; bedding structures absent	no	Eggshell and bone fragments; very disarticulated parts give evidence for violent transport conditions	Time of heavy rain either due to seasonal variability or to store events Very strong water forces.
Sandstone Sp/St	Calclitic, non-fossiliferous sandstone composed of angular pieces of quartz; bedding structures absent	no	no	Time of transition between heavy rain and moderate rainfall Strong water forces
Grainstone Fm	Marmorised, slightly sandy paleosols with calcitic nodules and iron staining; only slightly mud-supported; bedding structures absent	rare	Bones and freshwater invertebrate members well preserved	Time of moderate rainfall due to a transition of seasons or to a swelling off alter storm events Moderate water forces
Mixture between Grainstone and Packstone Fm/Fl	Marmorised paleosol that marks the transition from grainstone to packstone; bedding structures absent	moderate	Bones and freshwater invertebrate members very well preserved	Time in between moderate and hardly any rainfall Weak water forces
Packstone Fl	Marmorised, more marly paleosols with calcitic nodules and iron staining; mud-supported; some granular components present; bedding structures absent	common	Bones and freshwater invertebrate members very well preserved	Time with little to no rain during a dry season or during the absence of storm events Very weak water forces

Important characteristics of the strata are:

1. Repetition of facies in a vertical stratigraphic profile (figure 6)
2. Facies have limited lateral extent (figure 7)
3. Calcic paleosol characteristics:
 - i) a very consistent lack of bedding structure
 - ii) the prevalence of mottling in the paleosol sections
 - iii) isolated or groups of isolated gray calcareous nodules
 - iv) high porosity in the sediment

(after Khajuria & Prasad, 1998)
4. Terrestrial and freshwater fossils (Table 2, Table 3, figure 6, figure 7)
5. Mudcracks and a dipping erosional surface (figure 14)
6. Very localised root traces present in the paleosol facies underneath Eva
7. Paleosol facies are reworked marls incorporating a fine sand component and show a very consistent lack of lamination or paleo-soil horizon boundaries.
8. Rapid changes in the depositional environment from floodplains to main river channels in the Haute Vallée de l'Aude.

Table 3: List of floral and faunal remains at the site of Bellevue (after Bilotte, Koess & Le Loeuff, 1999).

<i>Plants</i>	
	<ul style="list-style-type: none"> • cycads • plams
<i>Invertebrates</i>	
	<ul style="list-style-type: none"> • gastropods • bivalves
<i>Vetrebrates</i>	
Fish	
	<ul style="list-style-type: none"> • Osteichtyes Lepisosteidae Lepisosteus sp. (Bonefish)
Tortoises	
	<ul style="list-style-type: none"> • Chelonia indet.
Crocodiles	
	<ul style="list-style-type: none"> • Eusuchia Allodaposuchus precedens • Mesosuchia Trematochampsidae Ischyrochamps meridionalis
Dinosaurs	
	<ul style="list-style-type: none"> • Sauropoda Titanosauridae Ampelosaurus atacis • Theropoda Dromaeosauridae Variraptor mechinorum • Ornithopoda Iguanodontia incertae sedis Rhabdodon priscus • Thyreophora Ankylosauria indet.
Pterosaurs	
	<ul style="list-style-type: none"> • Pterosauria indet.
Birds	
	<ul style="list-style-type: none"> • Gargantuavis philoinos (running bird)

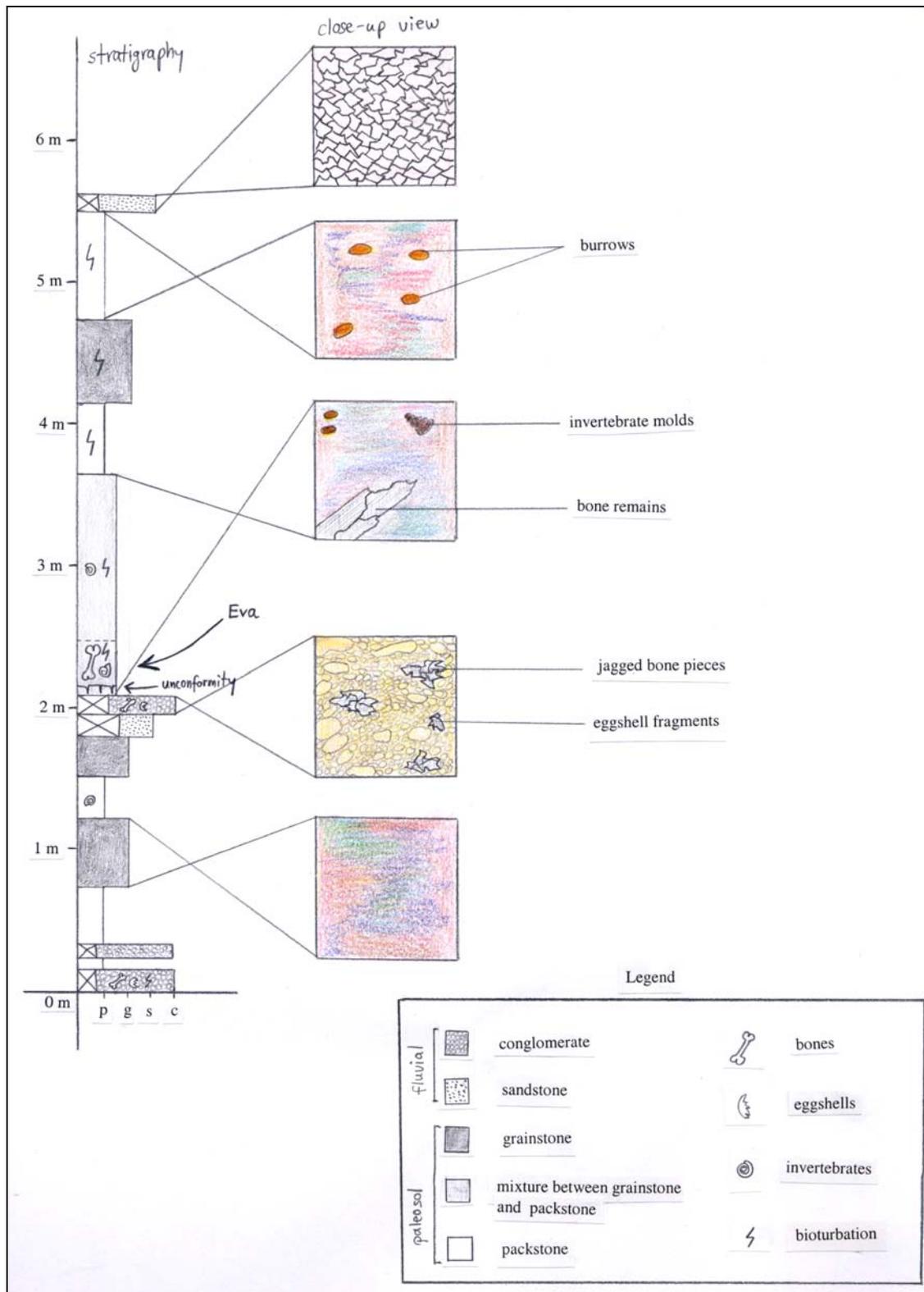


Figure 6: Stratigraphical profile of the sediment progression found at Bellevue. The three fossil levels present are referred to as fossil level one, two and three (from bottom to top) in the following sections.

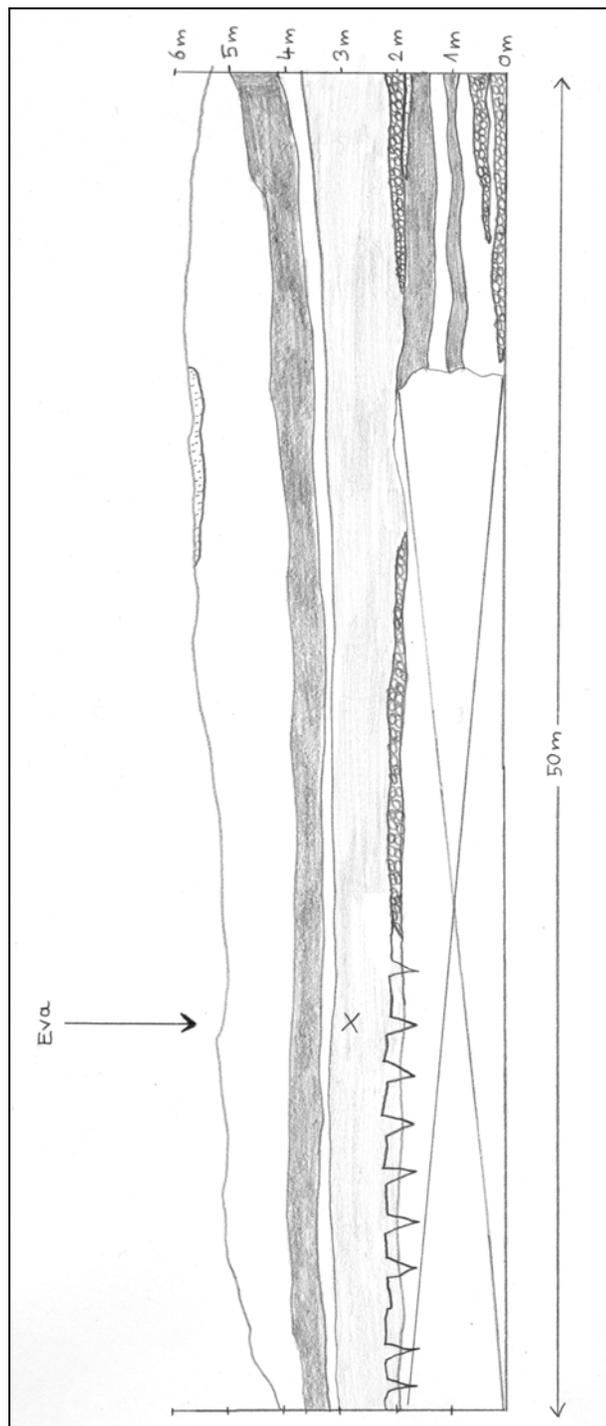


Figure 7: Lateral (west-east) stratigraphy variation along the site of Bellevue. The key is the same as for the stratigraphic profile.

 : Polygonal cracked surface filled with conglomerate and angular unconformity. Lateral extension is not known.

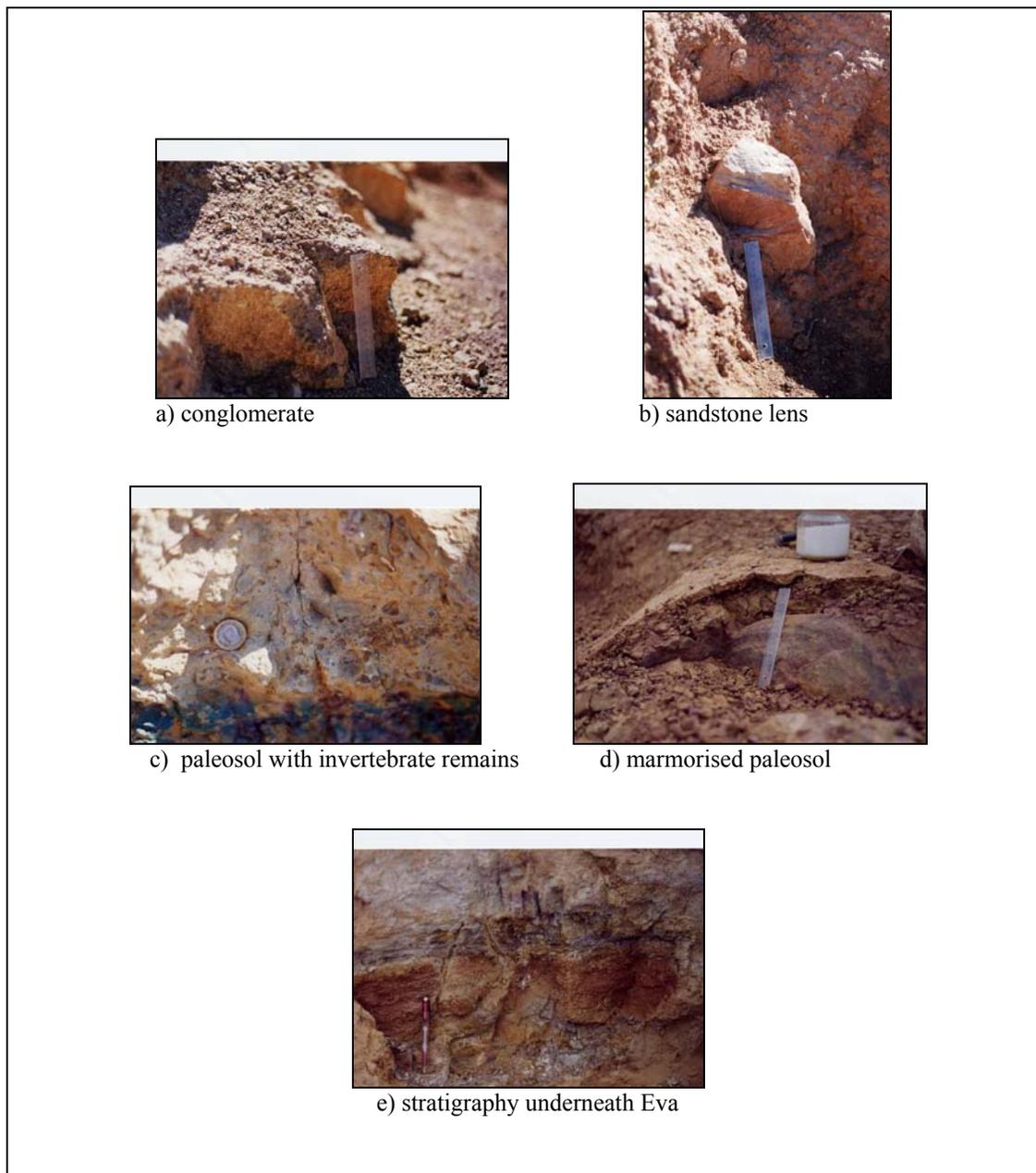


Figure 8: Pictures of the facies present at the site of Bellevue. The ruler is 16 cm long, the coin has a diameter of 1.5 cm. 8 e) shows the stratigraphy underneath Eva. The white mineral in the foreground is kaolinite. Root traces can be found in the dark brown sediment above the field of kaolinite. The pencil is 15 cm long.

The depositional environment

The ancient depositional environment as indicated by the strata at the site and the immediate surrounding region was a shallow fluvial setting in hot climate. The stratigraphic sequence found at the outcrop bears characteristics of three fluvial environments: a braided river, a meandering river, and a crevasse splay deposit in a floodplain environment immediately adjacent to the main channel. There are two difficulties in drawing solid conclusions about the nature of the sediments: a) Many braided rivers merge downslope into meandering rivers and the two channel styles are often quite difficult to distinguish from each other in ancient sedimentary sequences (Boggs, 1987). b) Crevasse splays that are large enough to reflect current domination are a major challenge to distinguish from small channel deposits of channels with a fine sediment load (Boggs, 1987).

From floodplains to rivers, from rivers to floodplains

An additional factor that increases the difficulty of assessing the exact nature of the sediments at the site of Bellevue is a frequent shifting from lake-dominated floodplain to channel deposits on the vertical stratigraphic sequence for the Haute Vallée de l'Aude (figure 9, figure 10). Because of these rapid shifts, usually continuous lake-dominated sediments (Boggs, 1987) are found to be cut off by fluvial sediments in the region of study. A very good place to see this, is the road cut at Belle Air, which is conveniently situated right beneath the outcrop at Bellevue.

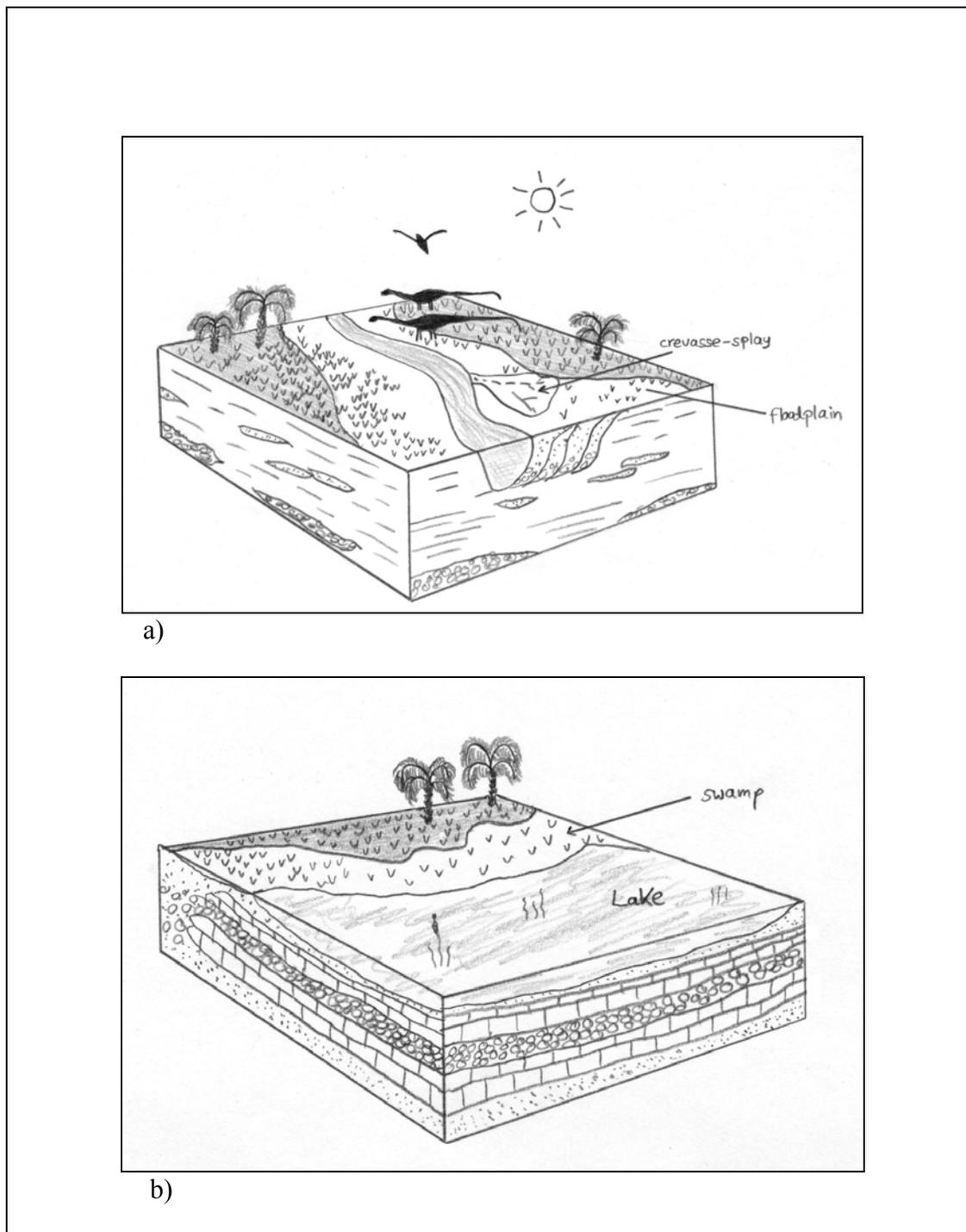


Figure 9: The two types of depositional environments in the Haute Vallée de l'Aude. The river (a) alternating with major floodplains (b) that form lakes and swamps. The limestone blocks represent calcite-dominated lake carbonate sediments.

The floodplain sediments are characterised by a lake-dominated carbonate facies that is entirely absent at the site of Bellevue (figure 10), although the percentage of calcite present at the site (calcic paleosol facies!) is still very high. The absence of the carbonate facies at the site suggests that Bellevue underwent substantial channel influence, either by the main channel itself or by a large crevasse splay. Therefore, Bellevue must have either been at the channel margin or immediately adjacent to the main channel.

It is unclear whether or not the lake sediments are derived primarily from a shallow lake system or a lake-like floodplain. The reason for this uncertainty is that three different types of carbonates can be distinguished (figure 10). In the case of one type of carbonate deposit, an alternation of lighter and darker lamination bands gives evidence of the formation of varves (figure 10 d). At Belle Air, the varves owe their existence to sediment input from the river rather than to cold climate. The variable sediment input from the river can be explained by the seasonal variability on carbonate production of microorganisms that have been studied by Ina Groebke (2001). Greater carbonate production during the summer tends to mask fine organic matter, which accumulates very slowly throughout the year. Thus, an annual couplet is formed consisting of a very thin organic layer produced during the winter and a thicker, lighter coloured layer of carbonate sediment produced during the summer (Boggs, 1987). The second type of carbonate shows very fine, hardly discernible lamination (figure 10 e), whereas the third type (figure 10 f) shows no sedimentary structure at all. What the three types of lake-dominated floodplain carbonates show about the nature of the floodplain (depth, precipitation, etc.) is not the focus of this

study, however the differences in the carbonate deposits give evidence of rapidly changing environments within the depositional environment: The floodplains changed considerably in nature over time.

The alternation between a fluvial and a lake-dominated floodplain depositional environment can be interpreted as the gradual subsistence of a foreland basin. The lacustrine carbonates only show a low content of terrigenous material (Groebke, 2001), suggesting a flat hinterland, an observation that is important for the paleoclimate (see section on climate).

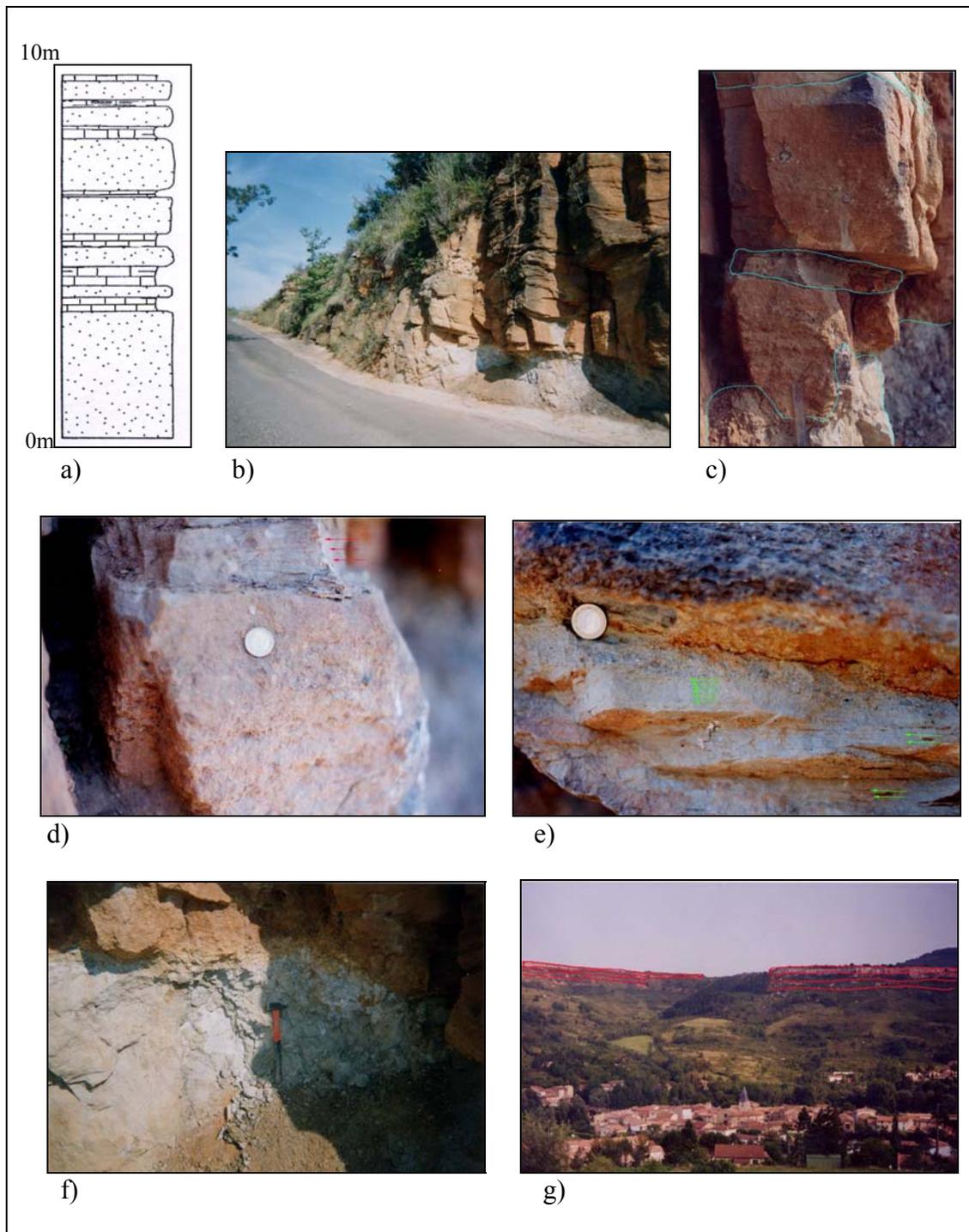


Figure 10: a) Stratigraphic column of the Grès des Estous formation at Belle Air, just beneath Bellevue. b) and c) Photos showing the carbonate facies alternating with the sand and conglomerate facies. The blue lines in c) indicate the carbonates. d) Close-up view of a carbonate deposit. The red arrows point to varve-like laminations. e) Close-up view of a carbonate deposit. The green arrows point to very fine, hardly discernible lamination. f) Close-up view of a carbonate deposit. No sedimentary structure was discernible. The hammer in the picture is 20 cm long. g) The trend of alternating floodplain carbonates with channel deposits is also true on a bigger scale. The red lines mark the carbonate deposits on the other side of Campagne-sur-Aude.

In contrast to this, the fluvial deposits are composed of conglomerate and sandstone facies that may or may not show sedimentary bedding structures. The exposed strata at the site of Bellevue can neither solely be attributed to sedimentation on a floodplain, nor to a pure river channel setting in either a braided river or a meandering system (figures 6, 7, 8, 11). Therefore, I have decided to present three possible hypotheses.

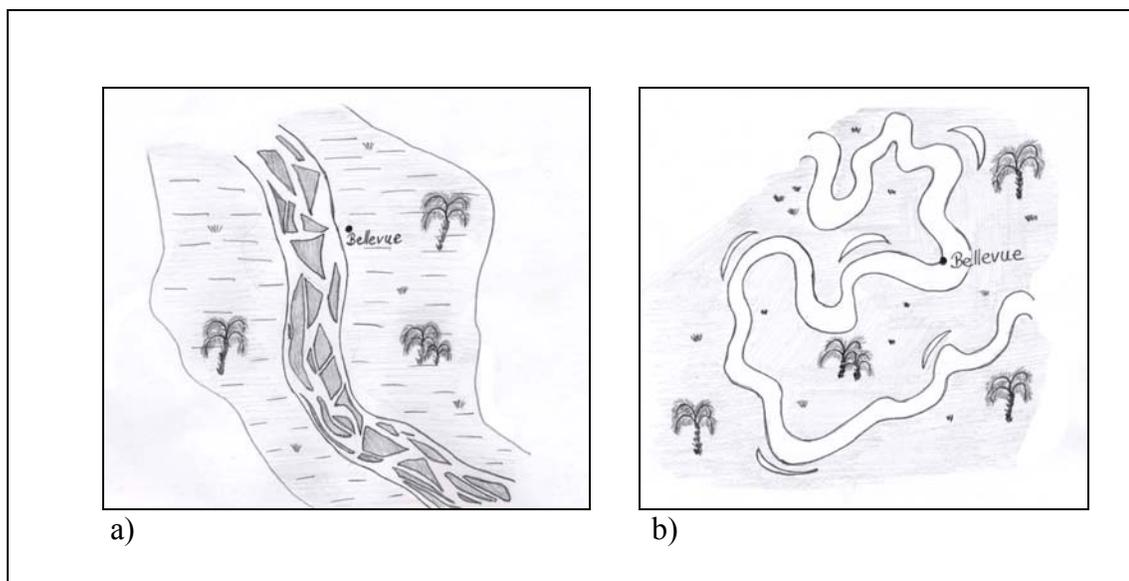


Figure 11: Where does the truth lie? a) Was Bellevue in a braided river or a crevasse splay in a floodplain? b) Was Bellevue at a point bar of a meandering river system with very fine bedload?

An ancient braided river system

The fast lateral and vertical changes in the strata found at the outcrop of Bellevue reflect a variation in water velocity as well as the geographical variability of the channel. This is characteristic of a braided river of overall slow-flowing water that migrated by the erosion of floodplain deposits (figure 12).

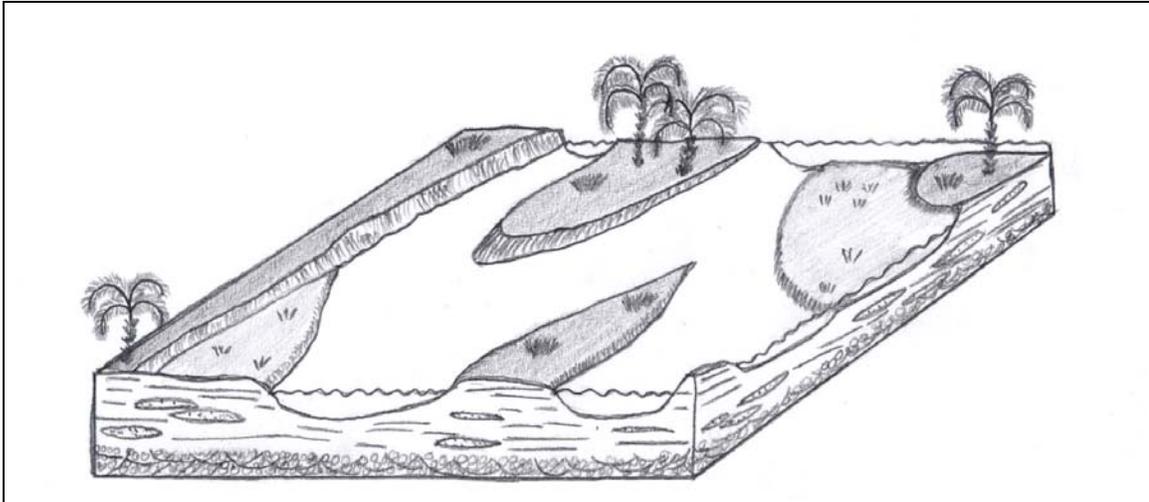


Figure 12: Block diagram showing one likely reconstruction for the site of Bellevue. The shallow braided river system migrated by erosion of floodplain deposits.

It is not clear how much vegetation there was around Bellevue, but certainly there was some (cf. table 3). The existence of vegetation along a river's banks tends to inhibit braiding.

The unstable margins that a braided river requires need to be explained by the nature of the sediments. The small gray calcareous nodules present in the paleosol facies indicate immature soils with high erosion potential (Groebke, 2001). Figure 13 shows the stratigraphic profile of a braided river with a generally fining upward trend. The sediments between metres 6 and 9 in the following stratigraphic column are very similar to the top half of the Grès des Estous Formation and the strata found at

Bellevue taken together (cf. figure 6). In-channel sands and conglomerates occur with occasional scour fills that are overlain by very fine-grained sediments that are followed again by sandstones.

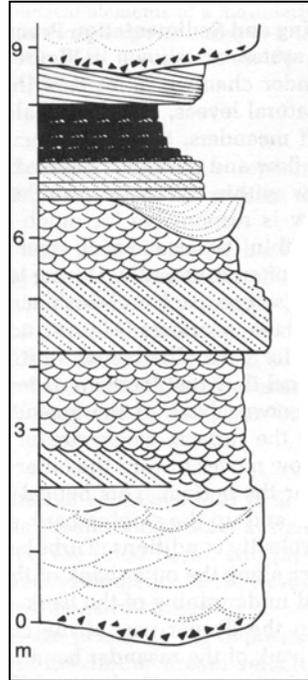


Figure 13: Summary of the vertical sequence of a braided river facies (from Boggs, 1987).

An ancient meandering river system

The stratigraphic sequence found at the site of Bellevue is also similar to ones found pertaining to meanders (Leeder, 1999; Miall, 1998). The following characteristics, all listed by Walker and James (2001) as typical for meanders, can be found at the site of Bellevue:

- i) The sediments are all fine-grained. This type of bedload is most often characteristic for meanders.

- ii) The paleobotanical fossil record, which consists mainly of cycad and palm remains, gives evidence of an abundant flora. Vegetation along riverbanks favours the hypothesis of a single channel.
- iii) Rivers in humid environments, like in a tropical climate (see the section on climate), are more likely to be meandering.
- iv) Meanders typically have waterlogged plant material and calcrete pebbles at their base, both of which are present at Bellevue.

Why is this model satisfactory? Every genetic unit at Bellevue can be interpreted as corresponding to a further deposit of a point bar in the internal part of a river with high sinuosity. The slight tilts of the beds and the lateral variations across the outcrop seem compatible with this hypothesis. The conglomerates at the bottom and the higher abundance of marly material at the top of the stratigraphic profile could be interpreted as a progressive filling of the meander (Proudhon & Schulp, 1993-1996). Figure 14 shows the second likely reconstruction for the late-Cretaceous site of Bellevue.

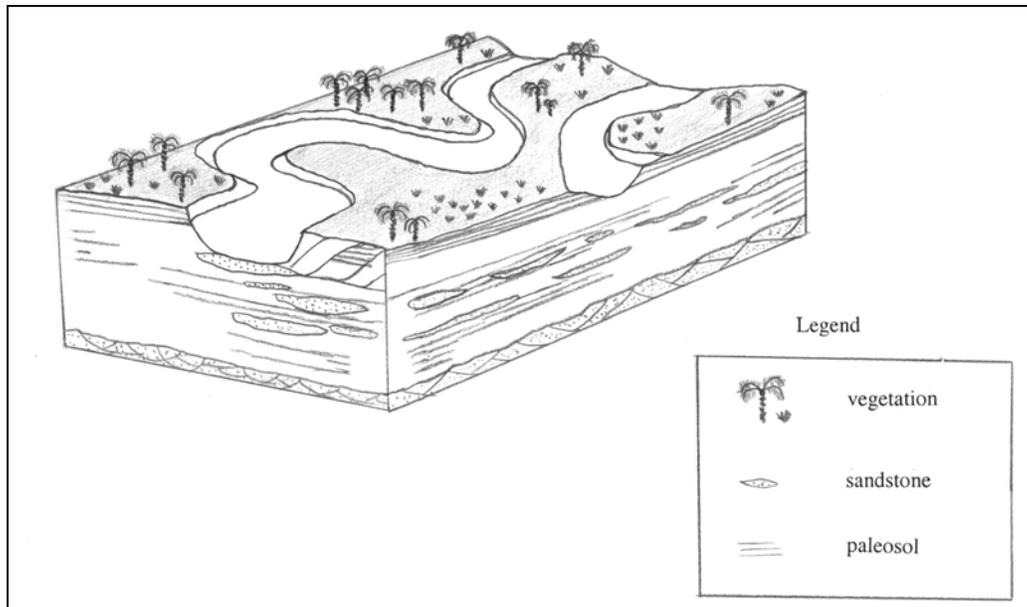


Figure 14: Diagram showing another likely reconstruction for the late-Cretaceous Bellevue and its surrounding area. The landscape around Bellevue was dominated by the meandering river, perhaps with occasional oxbow lakes. Vegetation along the banks was plentiful. The sandstone on the bottom showing cross-bedding represents the top portion of the Grès des Estous. The sediments in white are a different type of paleosol.

A deposit in an ancient floodplain

About 80 to 90 % of the sediments found at Bellevue pertain to paleosol facies. Unfortunately, I was unable to clarify the degree of continuity of the conglomerates at the outcrop, though at least some of them seem to be lenticular. The lenticular conglomerates and sands are interspersed as sheet-like structures, which are typical indicators for crevasse splays (Walker & James, 2002). The absence of clearly developed channel margins for the majority of time also speaks for a floodplain deposit (Russell, 2001). Figure 15 shows the classical fining upward sequence of a meandering river that ends in a floodplain accretion.

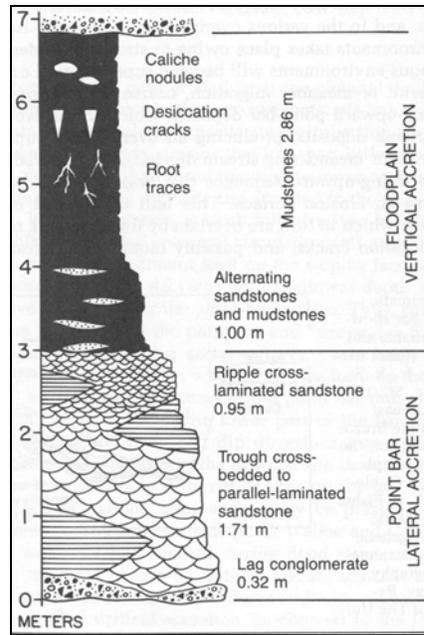


Figure 15: Classic fining-upward sequence in a meandering stream deposit (from Boggs, 1987).

Although Bellevue incorporates the above characteristics of a floodplain deposit, the paleosol facies show heavy reworking and a complete lack of stratification or paleo-soil horizon zonation. Root traces are present only localised, and the extent of the unconformity (figure 7, following section) is not known. Channel margins are absent for the most part, but left traces in two conglomerates. All this suggests that substantial influence from a major crevasse splay or the main channel at its margins must have played a role in the sedimentation at the site of Bellevue. Any further conclusions have to be left for further studies.

Unconformities

Two features on the same stratigraphic level at the site of Bellevue give evidence for an unconformity of unknown, yet possibly fairly short, time span. These

two features are a set of irregular, vaguely pentagon shaped structures that are filled with conglomerate, and a dipping surface (angular unconformity) whose lateral extension is not known. In my interpretation, the pentagons represent mudcracks in originally fine-grained sediment that were later filled with conglomerate after a time of non-deposition. The dipping surface marks an ancient river deposit that was eroded in the same time of non-deposition. Photos of both these particularities are shown in figure 16.

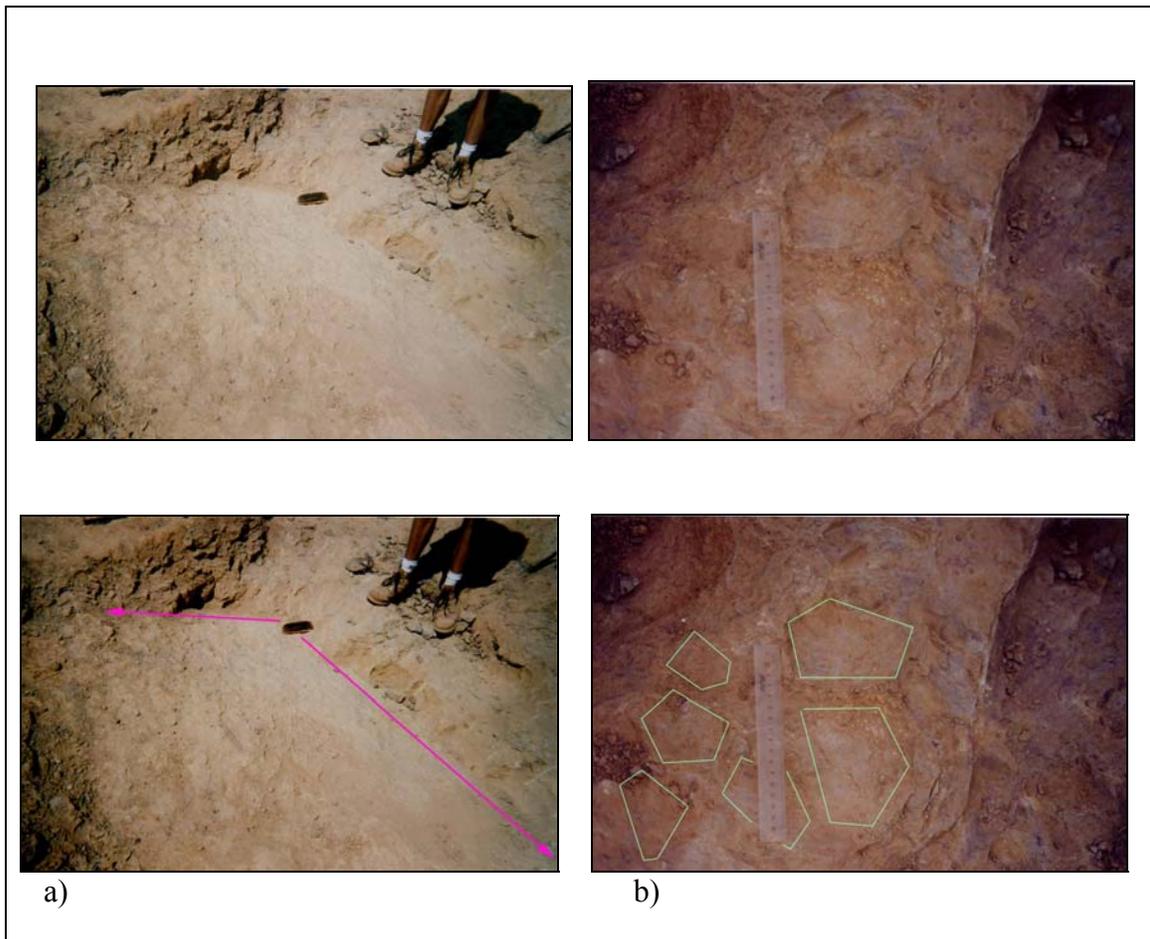


Figure 16: a) The erosional dipping surface (angle is about 30°), and b) the pentagon-shaped, conglomerate-filled mudcracks shown in plan view. The brush in a) is 12 cm long; the ruler in b) measures 16 cm.

An observation on the dipping erosional surface that might result in a better understanding about the processes operating during the time of non-deposition is shown in figure 17. The dune marks on the surface suggest that sediment erosion took place by eolian processes. The small dune belts have symmetric ridges and are of the longitudinal type. Winds from two directions must have eroded this surface during the time of non-deposition (Boggs, 1987). This dipping surface is the only dipping surface within otherwise horizontal strata. A possible interpretation is that a part of the originally horizontal and dried out mudplain was undercut by the river until it slid downwards. It then became buried in fresh, horizontal sediments (Davidson, 2003).

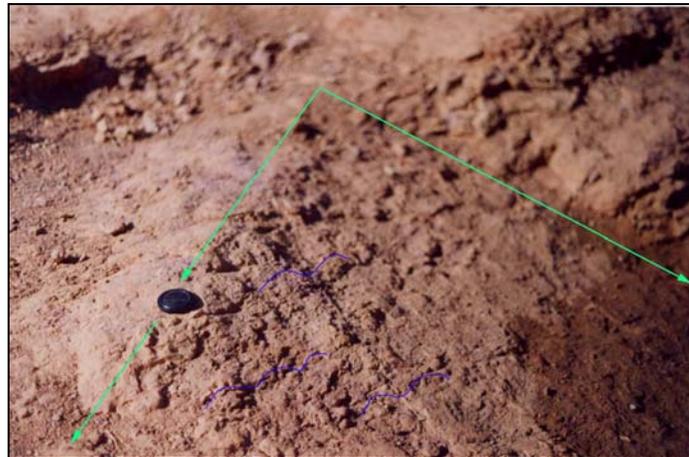


Figure 17: The dip of the erosional surface forming the angular unconformity is indicated by the two blue-green arrows. The dark blue wave lines mark the places at which the dunes are very obvious.

Mineralogy

The mineralogy at Bellevue is limited. The most predominant minerals are calcite, goethite, quartz, amorphous silica and kaolinite (in handspecimen only). In a previous mineralogical study done on the Marnes Rouges de la Maurine (Groebke, 2001), montmorillonite was additionally found in the bottom part of this formation. The paleosol facies, the marls, show different degrees of lithification and constitute about 90-95% of the Marnes Rouges de la Maurine. The percentage of carbonates (pure calcite) varies from 20-40%. Detrital quartz is present with grains of mostly siltsize.

Table 4 summarises the observations in the most important thin sections. Figure 18 shows pictures of six selected thin sections that were taken with a digital camera, model Nikon DXM 1200.

Table 4: Summary of the observations made in the most important handspecimen and thinsections.

<p><u>Thin Section Number:</u> A1 <u>Thin Section Name:</u> dinosaur bones <u>Observations in hand specimen:</u> Bone fragment very well compacted and intact; mainly brown, black and white in colour, some samples show red <u>Observations in thin section:</u> The bones have been fully recrystallised; Structural particularities include linearly, unidirectional bands of egg-shaped to irregularly hexagonal 'cells' with one dark pit in it <u>Minerals:</u> Amorphous silica -> chert (bone has solidified rather than calcified)</p>
<p><u>Thin Section Number:</u> A3 <u>Thin Section Name:</u> dinosaur eggshells <u>Observations in hand specimen:</u> Samples that are bigger than a 1 Euro coin are rare, most samples are smaller and have a pronounced surface structure on their outside <u>Observations in thin section:</u> the structure is made up of small angularly composed mosaics; many haircracks run along the surface of the eggshells; cracks are irregular in distribution, vary in size and length, as well as in sinuosity versus straightness <u>Minerals:</u> Calcite (100%), Fe – staining</p>
<p><u>Thin Section Number:</u> A5 <u>Thin Section Name:</u> Strata A <u>Rock classification:</u> conglomerate <u>Observations in hand specimen:</u> A fresh surface is yellow/brown/bronze. The rock is very hard. It fizzes easily in cold HCl, but the reaction is very quick (2-3 seconds). The grains are mostly subrounded with a small subangular component. They show high sphericity. The average grain size is 2 mm. The rock is not bioturbated. No grading discernible. <u>Observations in thin section:</u> circular to semi-angular grains of gray-brown matrix; pore spaces are filled with white, twinning mineral; white mineral crystallised in very unclean, angular plates which all show one distinct cleavage; in the grains there is Fe-staining of variable degrees; about 2/3 is clast support <u>Minerals:</u> Calcite (cement); mudstone, siltstone (clasts)</p>

Table 4 continued.

<p>Thin Section Number: A6 Thin Section Name: Strata B Rock classification: packstone Observations in hand specimen: Heavily marmorised, rather brittle reworked paleosol with small calcitic nodules and small (0,5 cm), elongate fossilised tubes of bioturbation. The colour is a mixture of red, orange, gray-green, purple and light brown. The grain size seems to be uniform: very fine to silt. The rock fizzes readily in cold HCl (16 seconds). This deposit has small, very broken bone fragments and also disarticulated pieces of dinosaur eggshells. Some goethite is present. Observations in thin section: uniformly fine grained; random Fe-staining present in patches; grains mostly show high angularity; gray matrix Minerals: Calcite; goethite</p>
<p>Thin Section Number: A10 Thin Section Name: Strata F Rock classification: grainstone Observations in hand specimen: Mostly red, purple and yellow fully marmorised rock. Rock is less well cemented and fizzes readily in cold HCl (12 seconds). Observations in thin section: grain supported rather than matrix supported; slightly Fe-stained patches; high frequency of mostly bigger, angular to subrounded crystal grains (mostly isolated) of high birefringence Minerals: Calcite; Mudstone blobs</p>
<p>Thin Section Number: A12 Thin Section Name: Strata H Rock classification: packstone Observations in hand specimen: Reworked paleosol with some calcitic nodules that are uncleanly distributed. The nodules are not bigger than 0,5 cm, are very well rounded and show high sphericity. The predominant colour here is gray green. The rock fizzes readily in cold HCl (6 seconds). Observations in thin section: Fe-stained; more matrix than grains is present (but not a typical packstone thinsection); single, relatively big and angular crystals of high birefringence are present between the matrix-filled cells ; small fragment of a dinosaur eggshell is present Minerals: Calcite, Goethite, Mudstone/siltstone</p>
<p>Thin Section Number: A15 Thin Section Name: Strata J lens Rock classification: sandstone Observations in hand specimen: The dimensions of the lens are as follows; height – 23 cm, width – 10,5 cm, depth – 7 cm; Its shape is rectangular; The lens is not fossiliferous, nor is it burrowed Observations in thin section: big, angular grains with low sphericity Minerals: quartz; calcite; chert; mudstone and siltstone particles</p>
<p>Thin Section Number: A17 Thin Section Name: Strata L Rock classification: grainstone/packstone mixture Observations in hand specimen: In the bottom 5 cm, the dominant colour is purple red. Towards the top the red component decreases steadily. There the dominant colour is gray-green and ferric brown. The rock is marmorised in bands rather than in patches. Invertebrates are present; gastropods, mollusks, brachiopods. There is bioturbation, bone fragments, calcitic nodules, crystallised quartz and galuconite (?) Observations in thin section: granular assemblage with some matrix support; Fe-staining in bands of variable thickness; Some very rare isolated islands of matrix-filled fields Minerals: Calcite; Quartz; Goethite</p>
<p>Thin Section Number: A23 Thin Section Name: Eva's Strata Rock classification: packstone Observations in hand specimen: Marmorised paleosol Observations in thin section: Small calcite fields; Huge crystals with high birefringence; Fe- staining both in patches and in bands; Plant fossil remain (?) Minerals: Goethite; Calcite</p>
<p>Thin Section Number: B1 Thin Section Name: regular bioturbation Observations in hand specimen: Small, mostly circular tubes Observations in thin section: Pure matrix Minerals: Calcitic mud</p>

Table 4 continued.

<p><u>Thin Section Number:</u> B2 <u>Thin Section Name:</u> Eva's bioturbation <u>Observations in hand specimen:</u> On average thicker and bigger than regular bioturbation; circular grains and streets of rills are present. <u>Observations in thin section:</u> Pure matrix <u>Minerals:</u> Calcitic mud</p>

Mineralogical particularities at Bellevue include overgrowth on single mineral grains, which are most likely due to slight temperature or pH fluctuations within the depositional environment, and the presence of small ferric bands, which are either a modern day ground water process or show the location of thin ferric veins (Haileab, 2002). Some of the quartz grains in thin section show splitting that has no preferred orientation. The presence of split quartz grains might suggest that the sediment previously was in a vadose zone, and later on in a phreastic one. There must have been an oversaturated carbonate-rich pore solution (Groebke, 2001).

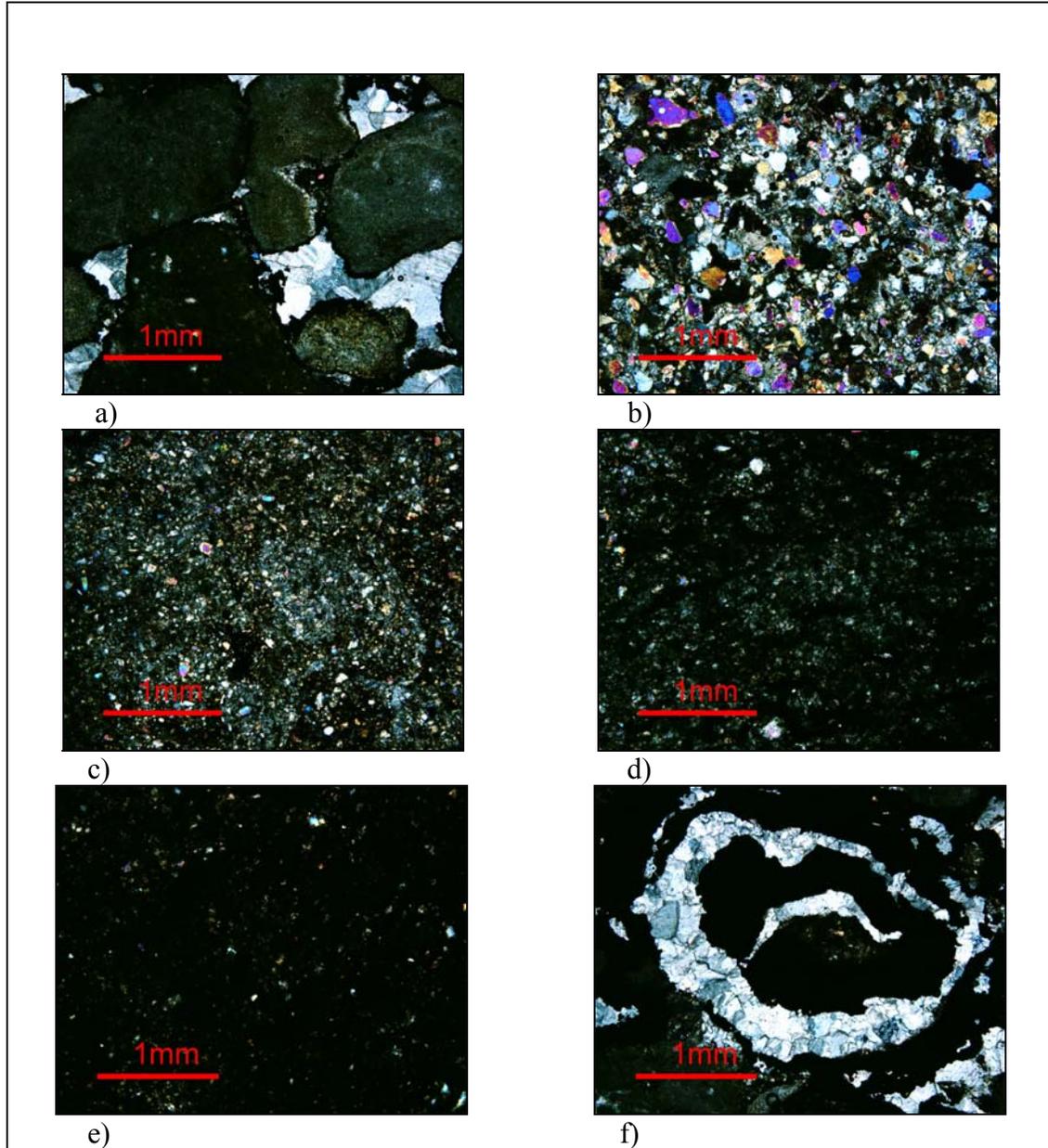


Figure 18: Pictures showing the different strata at the site of Bellevue in thinsection. a) conglomerate; b) sandstone lens; c) grainstone; d) mixture between grainstone and packstone; e) packstone; f) calcite rose. Note the difficulty of telling apart grainstone from packstone even in thinsection.

Goethite is a secondary mineral, resulting from weathering or local oxidation, and therefore is often present on the surface of rocks (Kerr, 1977). Quartz and

montmorillonite are ubiquitous minerals. At Bellevue, the primary or secondary nature of these two minerals is very difficult to assess. Amorphous silica occur in sedimentary rocks and represent compaction of ancient river sediments and paleosols. Kaolinite is a prominent clay mineral in sedimentary beds, which, when formed in situ, is an indicator of tropical conditions (Kerr, 1977).

During my fieldwork at Bellevue, the source for these ancient river deposits, especially for the siliciclastic material, could not be discerned. This is unfortunate, since a clarification about the provenance of the minerals would have helped with further discernation of the nature of the depositional environment. The Mount Mouthoumet Formation has been suggested as one possible source (Bilotte, 1984/85), but the proof for this hypothesis has to be left to further studies.

Climate

Cretaceous climate was warm (Crowley & North, 1991; Otto-Bliesner, Brady & Shields, 2002). During the Maastrichtian, southern France was closer to the Equator than it is today, which suggests a warm climate. Figure 19 shows the exposed landmasses during the Maastrichtian of what is Europe today. As is shown in more detail in chapter two, the strata at the site of Bellevue, including high-flow events to transport the conglomerate, could have been caused by a combination of seasonal heavy rains, occasional storms (not related to season), and/or changes in the river course.

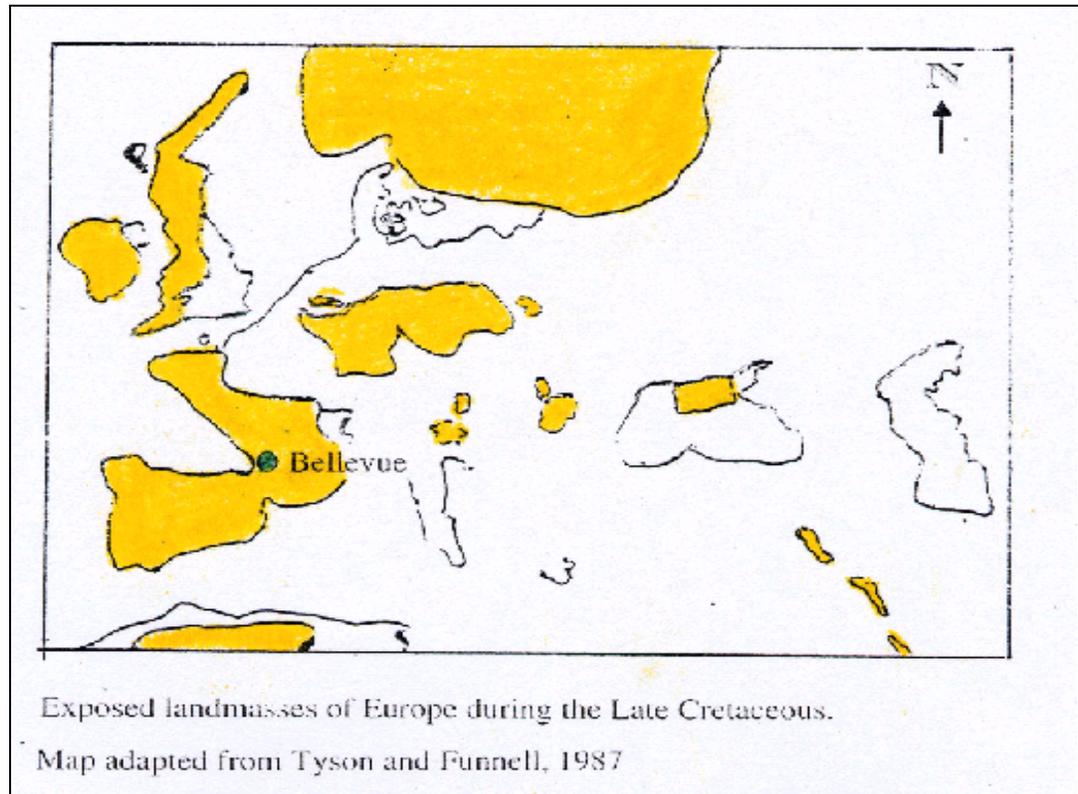


Figure 19: Map showing the location of Bellevue on the Late Cretaceous exposed landmasses. The paleo-latitude of Bellevue lay around 30° (from Albagli & Lurz, 2002).

There are two sediment features that speak for a hot, *semi-arid* climate:

1. The abundant calcareous nodules may have been formed by pedogenic processes and suggest a semi-arid climate setting (Russell, 2001).
2. The presence of an ancient calcisol indicates semi-arid conditions (Savina, 2003).

However, the presence of kaolinite and montmorillonite indicate an annual precipitation of at least 500 mm (Eslinger, 1988) in *tropical to subtropical* climate.

Precipitations that high in a warm, semi-arid climate can take place, but are mainly restricted to mountain belts or other regions of higher elevation. As I have shown in the section on stratigraphy, the hinterland region of the sedimentary environment was likely to be flat. Therefore, a tropical climate setting seems to be more plausible.

Apart from the Cretaceous position of France, there are two other factors that indicate a tropical climate:

1. The alternation between coarse-grained and fine-grained sediments, can be interpreted as alternations in tropical precipitation patterns, and marmorised paleosols are usually associated with tropical climates (Leeder, 1999).
2. Faunal and floral remains indicate a tropical setting. Crocodiles, cycads and palms are found in modern tropical climate zones.

Skeletal remains and Taphonomy

The taphonomical study on the preserved fauna at Bellevue is solely concerned with vertebrate fossils, and is aimed at the reconstruction of the post mortem/preburial and fossilisation history of Eva and the other animal rests. Studies on similar topics have been carried out for other sites (e.g. Dodson, 1971; Wood et al., 1988; Behrensmeyer, 1987; Smith, 1993). The raw data for the bones on which the taphonomical study was conducted can be found in Appendix 1. Figure 20 shows a schematic representation of the relative bone density distribution over the entire site.

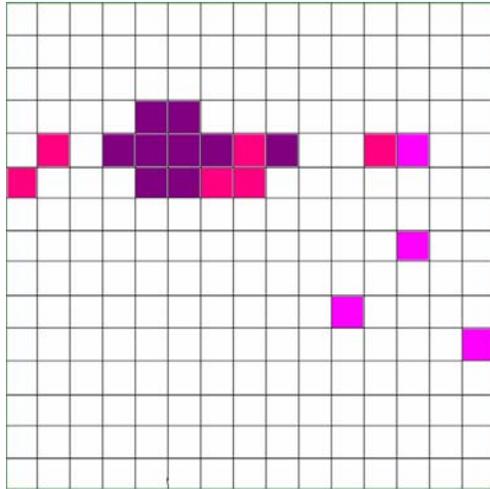


Figure 20: The scale is 1: 250; light pink: 1-2 bones; reddish pink: 2-5 bones; purple: 5 or more bones. This figure refers to all fossil levels. Plan view.

Approach

To complete a full taphonomic analysis of the bone remains found at the site of Bellevue during the summer of 2002, it was necessary to note the exact positions of all in situ bones at the outcrop. The entire formation at Bellevue was photographed multiple times from different angles at a distance to ensure sufficient overlap in case of doubt about the position of a bone. At each fossil, details of its degree of disarticulation, colour, permineralisation, surrounding sediment and potential pre-fossilisation fractures or abrasions have been recorded. The fossil richness of Bellevue and the lack of stratigraphic information before 1994, make it impossible to conduct a comprehensive taphonomic analysis. Where appropriate, I have incorporated Anne Schulp's (1995/96) work.

Articulation of the bones

Nearly all skeletal material recovered from the excavation at the site of Bellevue is unarticulated. In certain cases bones were found very close to each other, although not articulated, still suggesting a common provenance. The lack of carnivores with big enough teeth capable of damaging long bones, implies that predatory or scavenging activity has not been the paramount driving force for the disarticulation of the bones.

Bone weathering

The preservation state of the bones varies between heavily worn or completely broken to well preserved and complete, with an undamaged outer layer. In my classification of preservation states, I followed the model suggested for pre-fossilisation weathering by Behrensmeyer (1978). The different groups of this model are summed up in table 5.

Table 5: Pre-fossilisation weathering.

State of Bone	Characteristics
1	smooth, fresh-looking surface on long bones with longitudinal fissures; moderately well-rounded articular surfaces
2	some flaking and cracking of periosteal laminae with a few longitudinal fractures parallel to the shaft closing towards each end; articular surfaces still rounded
3	flaking of long bones along the edges of longitudinal fissures; articular surfaces flat
4	bones covered in longitudinal and radial cracks; articular surfaces flat and cancellous
5	dense periosteal bone has flaked off; inner cancellous bone shape is barely recognisable

Pre-fossilisation weathering is present to some extent at Bellevue, particularly in bones found on the same stratigraphic level as the features suggesting an unconformity (fossil level two). The amount of bone material of quality 3 or worse from these strata is quite high (figure 21). Often this material lacks diagnostic features and is not worth excavating. These bone pieces are either given to tourists or are thrown away. Other bones at Bellevue do not show this type of damage. I estimate that about 42% of the bones at Bellevue are of quality 5. The remaining 58% distribute themselves quite evenly among the other four categories.

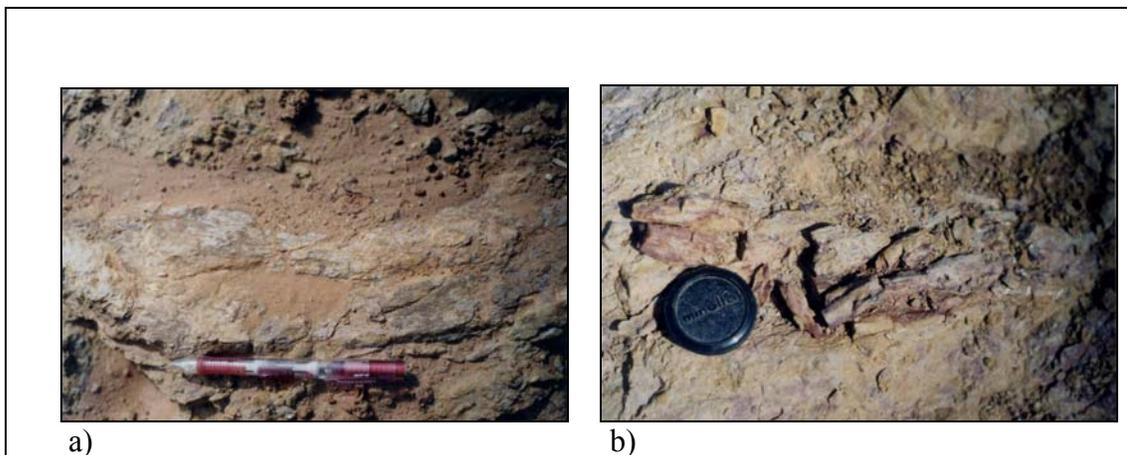


Figure 21: Pictures showing bones of different weathering states. a) The weathering degree on the bone lies around 3. The pencil is 15 cm long. b) The bone is completely weathered away. The camera lens measures 5 cm across.

Bone Fractures

Most bones at the Bellevue site are fractured at least once in their width. The same types of fractures occur on all fossil levels. I have been able to distinguish seven different bone fractures. Their distribution among the fossil remains is summed up in figure 22.

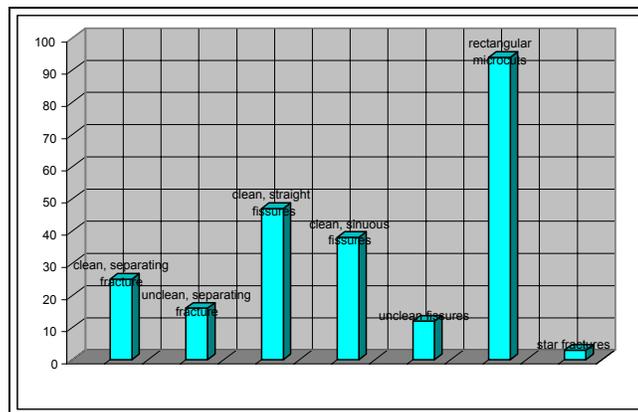


Figure 22: Percentage of bones that show a certain type of fracture.

The fractures are on a scale of 0,1 to 0,6 centimetres and vary in length and orientation within a given bone. A summary of bone fracture thickness can be found in figure 23.

Although some of the bones are clearly separated in two halves, only a minority of them is truly displaced. Many of the fractures occurred during the formation of the Pyrenees, when the bones were already fully fossilised (LeLoeuff, 2002).

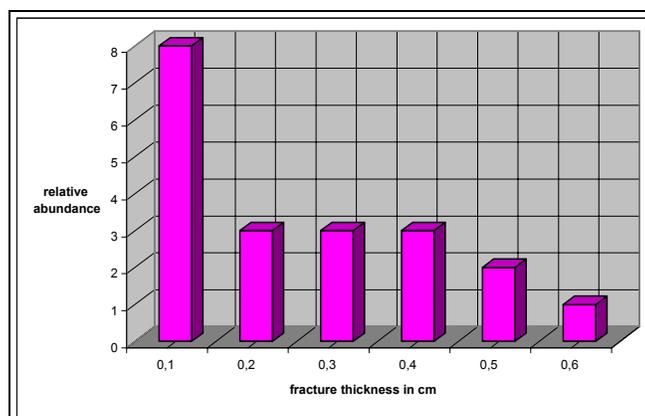


Figure 23: Relative abundance of fracture thickness

The most common fracture thickness and the most common fracture type, the rectangular microfractures, occur together in most cases. Detailed measurements of these fractures reveal that they are parallel and evenly apart from each other, mostly 0,3 to 0,6 centimetres. They are surface fractures, ranging in depth never more than 0,2 centimetres. Most of the rectangular microfractures are oriented either towards the NW or towards the NE. These directions coincide with directions of stresses during the birth of the Pyrenees (Bilotte, 1992), and hence reflect the uplift of the time. Tectonically, Bellevue is situated at the nick point of the following: In the north, the lithological units dip due north with about 25-30°, and are part of the field of synclines of Quiza-Arques. Towards the south, there is the very flat and broad field of anticlines of Puivert-Cardou. The very flat synclines of Rennes-les-Bains run from east to west. The orientation of all fold axes taken together, indicate that the main compressional direction was north-south, and is directly derived from the origin of the Pyrenees (Bessière et al., 1989).

Fractures phenotypically identical to the rectangular microfractures, but with a different orientation are due to modern day weathering processes. Bones left partially or wholly unprotected will show shallow, haircut-like fissures in their surface after only two or three years (Laurent, 2002).

As for the clean fractures, it can be assumed that the straight ones and the sinuous ones have the same external cause, and that their degree of sinuosity is most likely due to the type of bone in question and its internal structure (LeLoeuff, 2002). For instance, a weak rib, compared to a heavy femur, is more likely to show sinuous cracks, because it lacks equally distributed internal stability (Laurent, 2002). Because

these fractures lack a common orientation and displace the bones only very slightly when they truly bisect the bone, it seems that they must have occurred during a stage when burial was either partially or fully completed. Could they have originated because of unequal sediment distribution? Figure 24 shows a typically fractured bone at Bellevue.



Figure 24: A bone with fracture types commonly encountered. Note the different thicknesses, directions and degrees of sinuosity of various fractures that are generally mixed shear-tensile fractures.

The unclean fractures are more displacing than the clean fractures. A possible explanation for this is that an unclean fracture is created by more force than a clean fracture. More localised force could lead to more displacement. Could this imply that unclean fractures have occurred before the clean fractures (e.g. falling of the still living animal)?

The star fractures are the biggest in size and the least abundant type of fracture present. They give evidence of sudden high forces acting upon the bone. Do they represent events of heavy things falling onto the bones? Figure 25 shows one of the rare star-fractures at Bellevue.



Figure 25: One of the rare star fractures at the site of Bellevue in its typical appearance.

Studies done on long bone fractures of human remains (Todd & Rapson, 1987) suggest that there is a proportional relationship between the degree of bone breakage and in intensity of the forces that caused it. Whether this is also the case for any other type of fracture has not been documented.

Figures 26 to 28 show the orientations of all bone fractures on every fossil level without the microfractures, that are due to the origin of the Pyrenees, and without the star fractures for which no orientation could be measured. I have decided to lump the different fracture types together, since I was unable to discern a preferred fracture direction for different types of fractures.

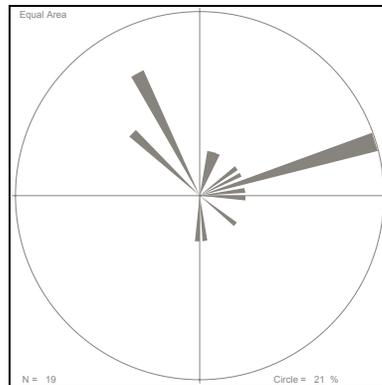


Figure 26: The preferred orientation of the bone fractures on fossil level one (cf. figure 6).

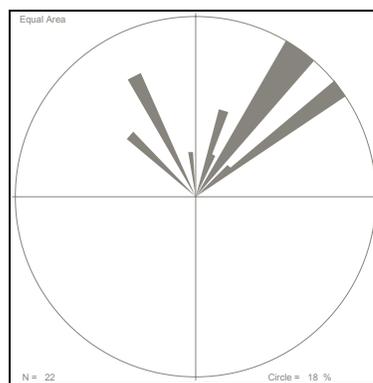


Figure 27: Preferred orientations of the bone fractures on fossil level two (cf. figure 6).

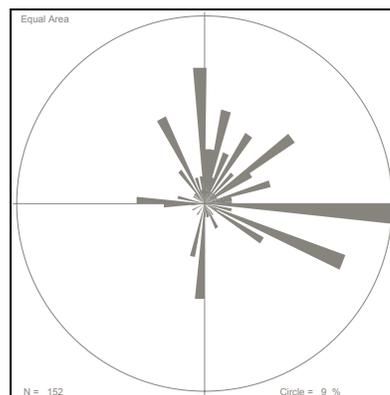


Figure 28: Preferred orientation of the bone fractures on fossil level three (cf. figure 6).

Although the figures show the orientations of all bone fractures except for the microfractures and the star fractures, the above rose diagrams have to be viewed with caution. First, the numbers of fractures present on every fossil level is dependent on the bone types and on the number of bones present. For example, fossil level one merely has three bones, and these bones are furthermore quite big and massive. Nevertheless, the figures illustrate two important points: a) different fracture types do not have different preferred orientations (as noted before), and b) there is a slight tendency for the majority of fractures to occur roughly perpendicular to the sense of current of the water.

Bone colour

Most of the skeletal remains found at Bellevue show a white to slightly beige colour with local patches of dark brown, black or bright red. These variations in colour do not reflect any particularities about the internal structure of the bones or taphonomical processes, but rather have to be seen as reactions to local metamorphism.

Stratigraphical distribution of the bones

The stratigraphical distribution of the skeletal remains is hard to picture. A quantitative estimate of the density of bone material from the different stratigraphic levels is not possible: Before 1994, the stratigraphic level of the fossils has often not

been recorded (see Proudhon, 1983). Also, Bellevue is very fossiliferous and has not yet yielded all of the remains present there (Duffaud, 2002).

The stratigraphical distribution of the general preservation quality of the bones, however, can be discerned. Different fossil levels reflect differences in transportational violence. There is a trend of preservation quality getting better towards the higher fossil levels. A study reflecting the same observation has been conducted by Schulp (1995/96) for earlier years in the excavation process at Bellevue. Her results are shown in the figure 29.

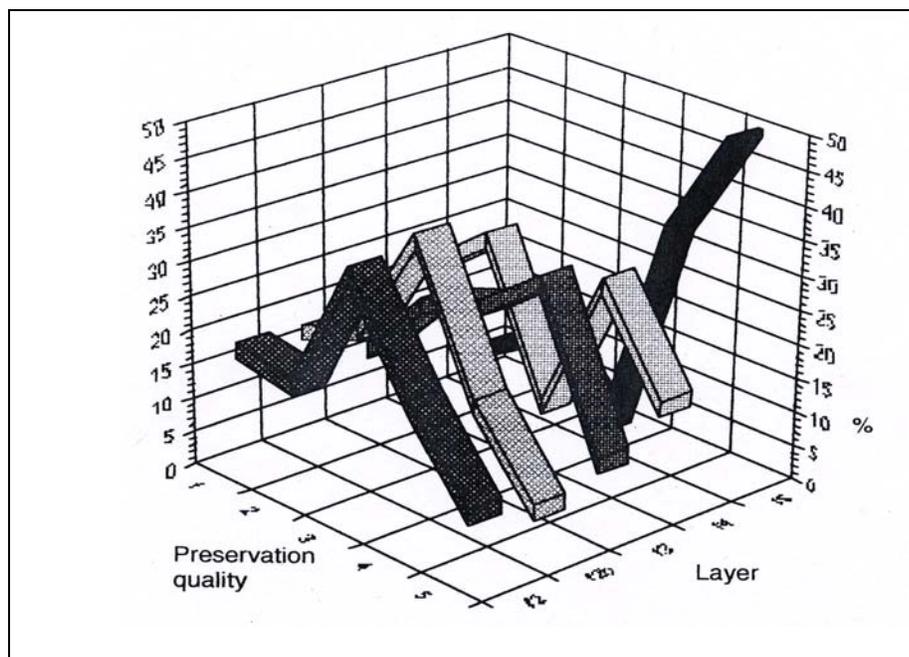


Figure 29: Preservation quality frequency distribution (Schulp, 1995/96). Here, the reader should not get confused with the use of the word “layer” in Anne Schulp’s figure. Anne Schulp had discerned five fossil “layers” (levels) in 1995, of which only three are still present at Bellevue.

The nearly complete absence of articulated skeletal material together with the high percentage of broken material towards the bottom of the Bellevue locality indicates a considerable amount of disintegration. The good state of preservation of

the bones found in the top fossil level, in which Eva was found (see section on Eva), suggests fossilisation in a relatively calm depositional environment. Since the transition between the two states of preservation is gradual, it can be assumed that the river or crevasse splay lost its violence over time.

Bone orientation

Individual bones at Bellevue show various orientations. The bones nevertheless fall into two general categories when the scale of observation is enlarged: parallel or perpendicular to the ancient water current. Smaller bones such as ribs or the shoulder are orientated parallel to the paleo-water current, whereas longer and heavier bones, are perpendicular to it. These observations stand in accordance with Coard (1999), who states that bones such as the pelvis, the scapula and ribs are good indicators of flow direction, whereas a set of dorsal vertebrates is not. The reason for this is that smaller bones are more likely to get caught on pebbles than big bones, hence deflected in their preferred orientation. Figures 30 to 33 show bone orientations specific to every fossil level.

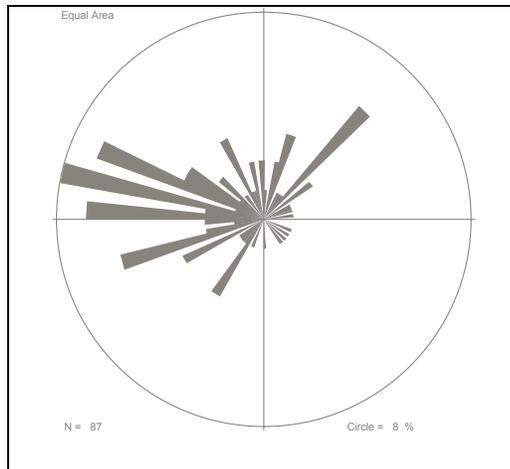


Figure 30: Rose diagram showing the preferred orientation for all bones in all fossil levels taken together.

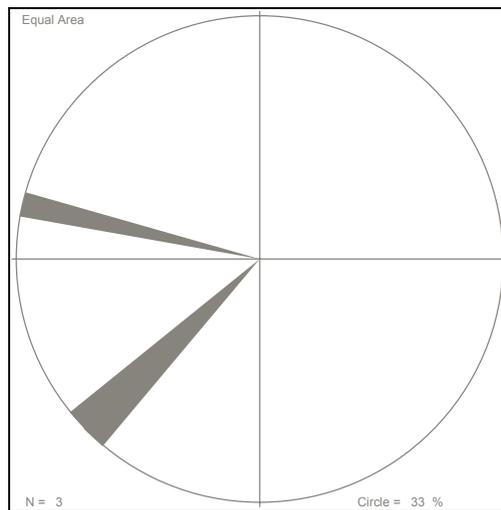


Figure 31: Preferred bone orientation for bones in fossil level one (cf. figure stratcolumn).

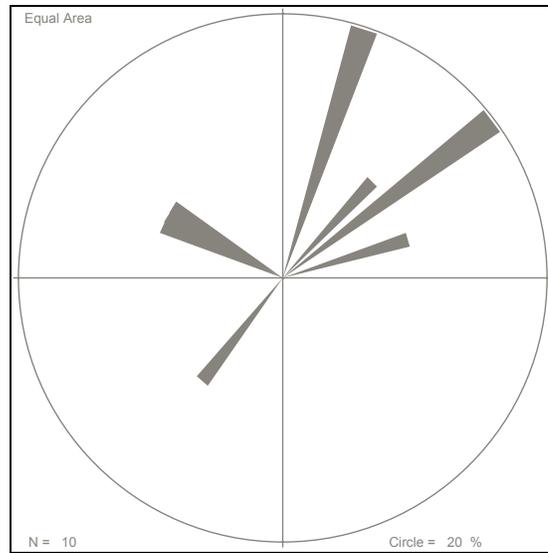


Figure 32: Preferred bone orientation of bones on fossil level two (cf. figure stratcolumn).

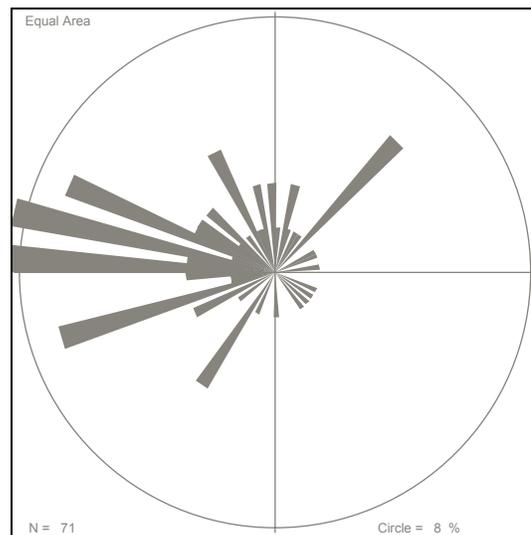


Figure 33: Preferred bone orientation in fossil level three, the level in which Eva is found (cf. figure stratcolumn).

Eva

Figure 34 shows a schematic drawing of the main part of Eva's skeleton. The lines on the bones indicate fractures. As can be seen from the figure, Eva's skeleton is unarticulated, but related bones are found in close proximity to each other. The bones are well preserved, and hardly weathered. Eva's bones are mostly white or beige in colour (figure 35) with only occasional dark brown, black or red patches.

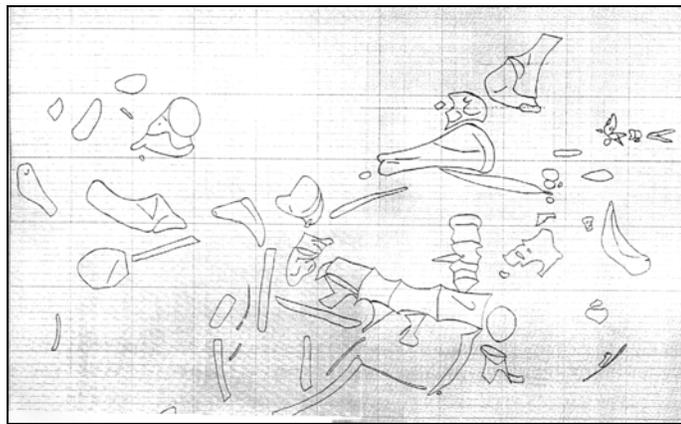


Figure 34: 1:10 drawing of the main part of Eva's skeleton; N is up.

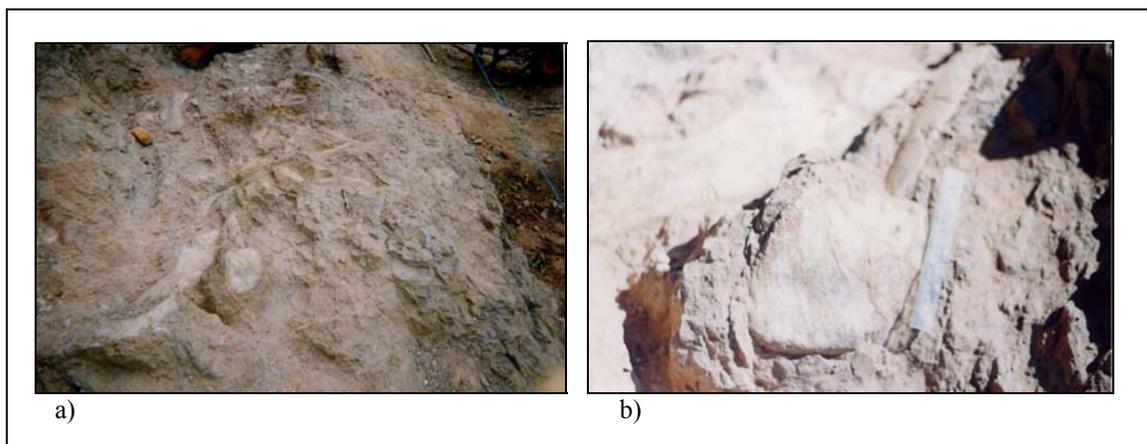


Figure 35: Note the good preservation quality and the light colours of the bones of Eva's skeleton (a) and in a close-up view of her shoulder (b).

Figure 36 shows the orientations of Eva's bones. Of all skeletal remains found at the site of Bellevue, Eva is not only the most complete, but also the best preserved. Why is she so outstandingly well preserved? As is discussed in the section Eva's death, it is very likely that she drowned. Her complete carcass possibly only floated to the next point bar of the river or got washed out a very proximal crevasse splay, whereas all of the other bones have reached the place of fossilisation individually.

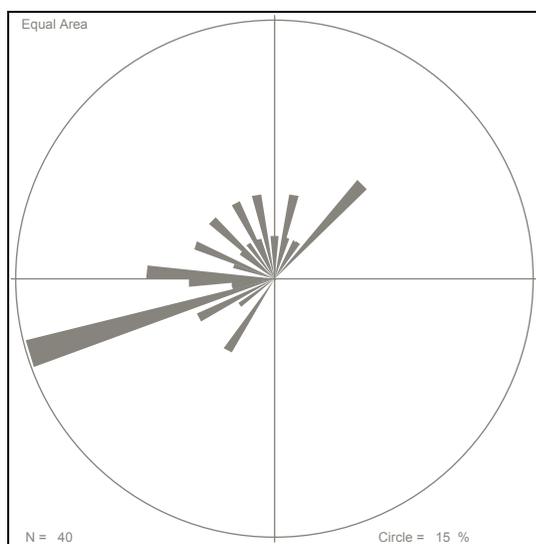


Figure 36: Rose diagram showing the preferred orientation of Eva's bones. The bones oriented SWW-NEE are long and heavy bones. The bones pointing towards the NW are smaller bones. Eva's bones reflect the overall trend of bone orientations at the site of Bellevue. Small bones are parallel, large bones are perpendicular to the water current, which was NW-SE.

Although the skeleton of Eva is nearly complete, some tail vertebrates, her feet and her skull are missing. With her skull missing, Eva places herself well within the typical record of recovered titanosaur skeletons. Skulls of titanosaurs are rare and the anatomy of their heads is to this day poorly understood (Trivedi, 2001). In most

cases, remains of this sauropod species are found without the head (Carrano, 2001). This phenomenon might be due to anatomical features, to scavenging strategies, or to bone transport potentials.

Bone transport potentials

Eva and the other animals present at Bellevue died in a river system, a setting where water currents dominate. The problem of assessing whether bone assemblages are allochthonous or autochthonous, is a central one, especially in ancient fluvial deposits (Behrensmeyer & Dechant Boaz, 1980; Wood, Thomas & Visser, 1988). Experiments of bones in flumes (Coard & Dennell, 1995; Coard, 1997) show that wet, dry, articulated and disarticulated bones have different hydraulic transport potentials. In these studies, wet and disarticulated bones are reported to have the least transport potential because of their decreased surface area exposed to the water force. In contrast, dry bones show a very high transport potential also in low to medium velocities. The reason for this lies in the fact that dry bones are buoyant and can therefore be transported on the water surface.

In the attempt to identify the factors that influence bone transport potentials Coard (1997) constructed velocity functions with different bone attributes, such as their size, weight, density and volume. Following statistical analyses showed that no bone characteristic is particularly influential on its transport potential. The highest scoring traits are articulated bone surface areas, wet volume and density, as well as dry volume.

The density of individual bones has also been proposed as a probable indicator of transport potential (Boaz & Behrensmeyer, 1976), although the question of how good the analogy of hominid remains is for a titanosaur has to be reserved for future studies.

In other analyses (Hill & Walker, 1972; Shipman, 1981) the shape index of bones has been suggested for the degree of water-sorting of a given bone assemblage. Although statistically the shape index emerges as significant in only one type of bone, the surface area was found to be a good indicator of transport potential also in these experiments. That an increased cohesiveness between the sediment load of the river and the greater surface area of the bone should also exist, thus increasing frictional forces, does not seem to have any major importance (Hanson, 1980; Coard, 1999). In most experiments, the sacra and individual vertebrates have been found to be the most transportable elements of disarticulated bone assemblages (Coard, 1999). Figures 37 and 38 show the relative occurrences of titanosaurid and ornithopod bones at the site of Bellevue:

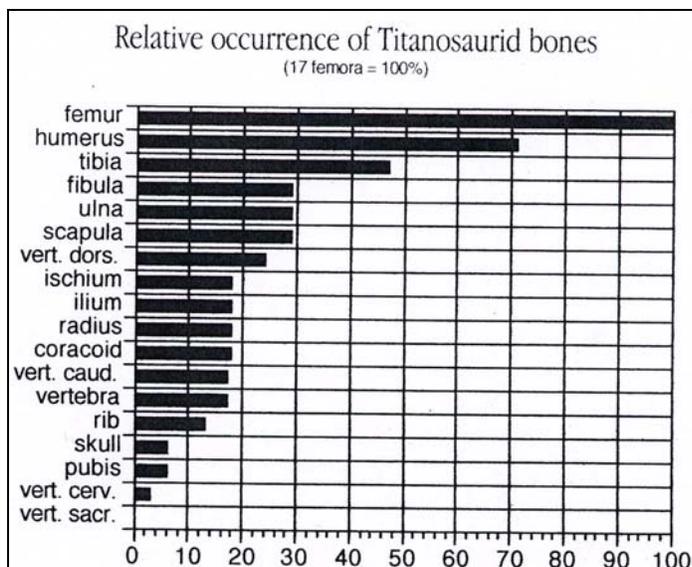


Figure 37: The occurrence of Titanosaur bones, as related to the number of femora (which are set to 100%). This graph gives an impression of the relative durability of the different bones of titanosaurs.

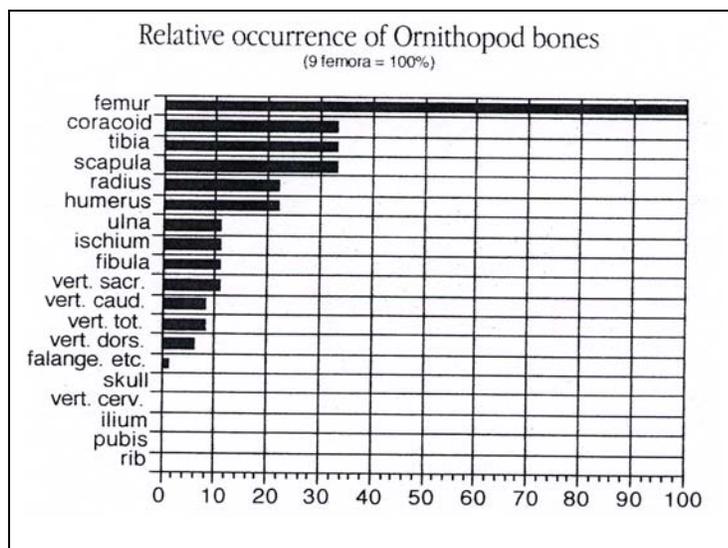


Figure 38: Occurrence of Ornithopod bones, as related to the number of femora (which were set to 100%). This graph gives an impression of the relative durability of the different Ornithopod bones.

In both cases, individual vertebrates and sacra fall among the least represented bones at Bellevue. It is a possibility that bones not pertaining to Eva came from carcasses that were more disarticulated before immersion into the water (scavenging activities?), and therefore became more dispersed in the current. However, the absence of well-preserved bones in the lower fossil level, indicates more violent transport potentials.

Due to the absence of literature on the transport potential of fresh, partially defleshed bones, an additional data collection had to be carried out. I experimented with a freshly killed young female racoon (Margaret). Figure 39 shows pictures of Margaret and me.



Figure 39: a) Margaret; b) I am defleshing Margaret.

During the process of skinning and defleshing Margaret, it became evident that different body parts had very different potentials to be dissected. Table 6 shows a summary of the dissection potential of Margaret's body parts on an arbitrary scale from 1 (very difficult) to 3 (very easy).

Table 6: dissection potential of different body parts.

body part	dissection potential
head	1
ribs	2
spine	1
legs	3
feet	1

I chose to spend an equal amount of time on each body part, selecting the time interval needed to almost clean the easiest part to deflesh completely. I interpreted the dissection potential to be an indicator of relative decomposition rate. Parts that could be taken apart only with great difficulty were left in the state they had obtained in the period of defleshing. This method yielded the following experimental bodies: two disarticulated feet with fur, two disarticulated very much defleshed front legs, two articulated back legs (one very defleshed, the other marginally defleshed), the ribcase coated with a thin layer of flesh and fat, the spine (left articulated and fleshed), as well as the head, which was impossible even to skin in the allotted time.

Immersion of these parts into Spring Creek yielded the following results:

- 1) As has been stated by Coard (1997) disarticulated bones have the least transport potential, also in a fresh and partially fleshed state.
- 2) The head travelled furthest in the least amount of time. The feet with fur on them travelled the least. If at all preserved, should we look for Eva's skull downstream in the future? Can it be assumed that her feet are upstream? Can the rest of the fossil assemblage with its poor representation of sacra and individual vertebrates be explained by bone transportation potentials of partially defleshed bones?

The location of Bellevue within the ancient river system

This section elaborates more on the uncertainty about the exact location of Bellevue that has been explained in the section on Sedimentology. A transportation potential experiment with a dead male squirrel (Genaro; figure 40) shows that there are several parts in a river at which a carcass could settle down.



Figure 40: A squirrel like Genaro.

The carcass was inserted into Spring Creek and was then observed, followed and repositioned for several hours. Genaro's body came to a prolonged rest at the following places:

- i) under an indentation under the root of a tree, bordering directly at the river
- ii) at a major stone in the middle of the river along which Genaro sank
- iii) a point bar
- iv) at the bottom of a small waterfall
- v) between branches and decomposing wood in the river

vi) on a very shallow part in the middle of the river

As evidenced by the different fossil levels and the richness of vertebrate material, deposition at the site of Bellevue must have been a fairly common and regular event. For this reason, the likelihood of Bellevue representing an old margin, point bar or current influenced floodplain is very high, although there are several other possibilities as shown in the experiment with Genaro.

Nature of the skeletal remains

The faunal remains at Bellevue, with the exception of Eva, constitute an allochthonous bone assemblage with an unknown source, since most bones are found isolated, and show signs of wear. The nearly complete skeleton of Eva, however, has to be regarded as a locally derived, autochthonous bone assemblage. If Eva's head was disarticulated very early in the stage of bone settling, the skull was probably left upstream since mandibles have a very low transport potential (Coard, 1999). If the head was still very articulated, it was deposited further downstream (experiment with Margaret). A more detailed analysis about the provenance of the bones at Bellevue cannot be conducted in the frame of the present study, because the degree of spatial resolution required for such an undertaking is extremely high (Behrensmeyer, 1991). Since I have worked primarily at the site of Bellevue and only marginally in its vicinity, data for such a high spatial resolution has not been collected.

Eva's Death

For an organism to die, there exist thousands of possibilities! This section is aimed at a short discussion of the most probable reason for Eva's death.

As is shown in the section on Taphonomy, Eva's skeletal remains are very well articulated and nearly complete. Analyses of the bones reveal that Eva was healthy. (LeLoeuff, 2002). For this reason, major illnesses that would have left marks on the bones, such as certain types of cancer, as a cause for death can fairly safely be ruled out.

Eva's bones lack gnaw marks, suggesting that her carcass underwent marginal or no scavenging. Since no evidence of carnivorous activity can be found on Eva's bones, she must have died at a place, where she was not easily accessible.

Modern animal studies show repeatedly that animals are intelligent. Titanosaurs lived near rivers and in floodplains. Eva was 12 years old at the time of her death (Duffaud, 2002), meaning that she had 12 years of living experience around the river. How likely would it have been for her to misjudge the river or its banks? Had it been likely, why did she not die at a sooner age and why is Bellevue not an outcrop bearing millions of other titanosaur bones? Accidents happen and they can happen to anybody and therefore are a possibility, but how likely are fatal accidents to happen?

The following paragraph presents the most probable cause for Eva's death, without wanting to rule out accidents, death by lightning, etc.

Although Eva was used to her environment and especially to the river, she might not have been used to predators, because of her age. Among the fossil assemblage at Bellevue, variraptor remains have been found. Variraptors count among the most intelligent dinosaurs known and it has been suggested that they hunted in packs (Keesey, 2001). Because variraptors are believed to have been rather intelligent, it is understandable why they would have attacked a young titanosaur rather than a full-grown, bigger and heavier adult. Suddenly finding herself surrounded by a group of hungry variraptors, would have doubtlessly caused panic in Eva. Modern animal and human observations show that extreme stress situations often lead to completely irrational reactions. Scared, Eva could have stormed in direction river. In her hasty flight, she might have entered the river and went into the water too far. Whether or not her neck was immersed into the water, the current proved too strong, caused her to lose balance, fall and drown. From her place of death, she then was then transported for a minimal distance, until her carcass came to rest at the place where she would be fossilised. This hypothesis is supported by the bone orientation: Eva's legs point into the current of the water.

Chapter Two

Further thoughts on the site of Bellevue

" Imagination continually frustrates
tradition, that is its function."

- John Pfeiffer.

The following section is dedicated to the scientific exploration of hypotheses concerning the paleo-environment at the site of Bellevue. Three major questions are addressed:

1. How could the sediments present at Bellevue have formed with respect to a tropical climate setting?
2. Can the dimensions of the old river or crevasse splay be approached?
3. What does the paleo-living environment based only on the fossil record of 2002 look like?

The reader should understand that I have taken a very oversimplified approach in my primary attempts of answering these major questions. There are multiple reasons for this: The time and resource constraints in which this study was conducted did not allow for more elaboration on the above matters. The nature of the questions asked furthermore brings difficulties with itself. Ecological reconstructions, for example, must necessarily be tentative, even when done for modern environments. The complexity of natural systems and the fact that ecological studies have the tendency of being based on a single census at a single point in time, render accuracy and full comprehension virtually impossible. Besides, some aspects of the questions addressed, such as "scale modelling", are clearly interdisciplinary and ideally should be tackled by a group of people with varying backgrounds, not only by myself.

Why did I nevertheless choose to have an entire section of my work be dedicated to the pursuit of inaccurate answers for eternally complex questions? First of all, the word "inaccurate" does not mean "completely wrong". On some level, my approaches to the above questions provide first valuable insights into the complex

answers for the problems. Besides, errors, as long as they are thoughtful errors and are labelled as such, are important things to share in a scientific community. Problem solving in science often works like engineering: We can only construct a working motor, if we are prepared to look at all the parts available to us.

The tropics, precipitation, storms and migrating rivers

The Late Cretaceous is poorly understood in terms of local climatic developments and in terms of rates at which these processes operated (Bice, 2002). The rates at which any processes operated at the site of Bellevue are virtually impossible to reconstruct due to the absence of absolute indicators of time, such as varves, tree rings, or invertebrates with annual growth rings. I suppose that the single sediment layers, especially when fossiliferous, do not represent very much time. The high degree of Eva's completeness and her excellent preservation quality suggest very little time for burial. This section focuses on why the sediment layers at the site of Bellevue are present and tries to approximate the time frame during which they could have been deposited. In a first attempt to tackle this difficult and complex question, I have decided to distinguish between three basic hypotheses, 'endmembers', for how the sediments could have formed: regular precipitation, storm events and lateral migration of the ancient river. In the following sections, all of these hypotheses shall be discussed.

Hypothesis 1 – Tropical Aw-climate

If the conglomerate and the finer grained deposits are interpreted as different seasons of a tropical wet-dry climate, it is possible that Eva's climate was an Aw-type climate. According to Köppen's definition of type-A (tropical) climates (Britannica Macropedia, 1998), an Aw (tropical wet-dry) climate has distinct wet and dry seasons, with most of the precipitation occurring in 'summer'. Total amounts of rainfall are less than in other tropical climate types, most of which occur in convectional thunderstorms. The dry season is clearly distinct from the wet season and temperatures are high throughout the year. The general shape of the annual precipitation distribution graph of a modern Aw-climate is shown in Figure 41.

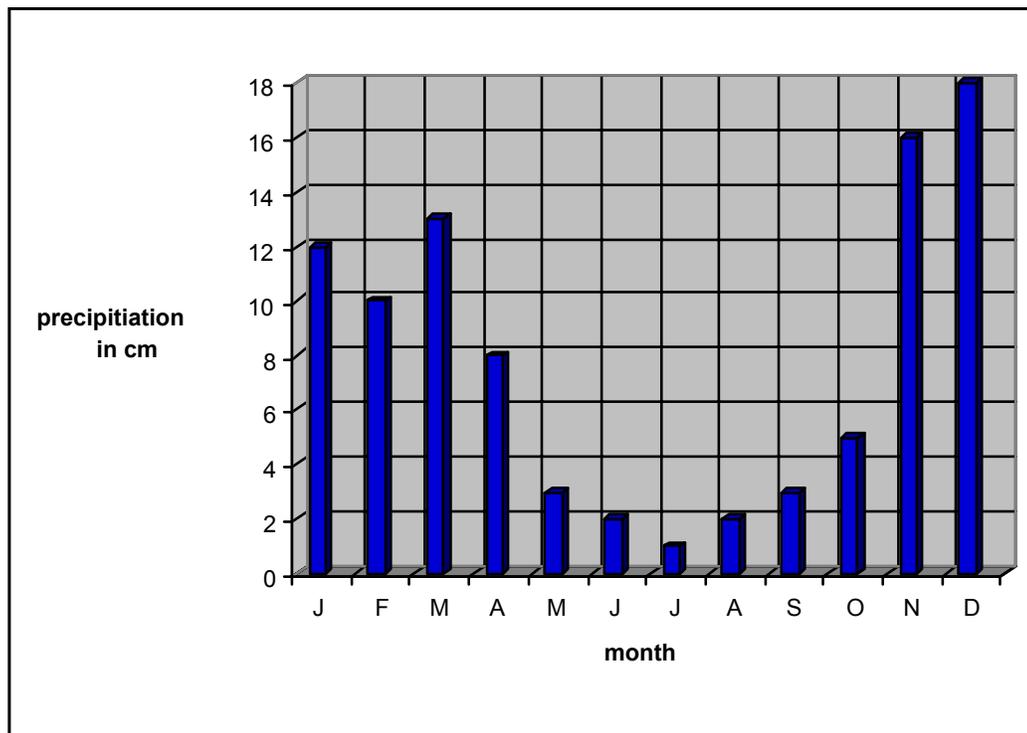


Figure 41: Annual precipitation distribution in a modern tropical wet-dry climate; Caetitit, Brazil (from Britannica Macropedia, 1998). The fact that Caetitit is located on the southern hemisphere might mean that the tropical precipitation pattern in the northern hemisphere is inverted, but does not pose a major disturbance for the thoughts proposed here.

One possible explanation for the sediment progression at the site of Bellevue within the framework of an Aw-type climate is shown in figure 42.

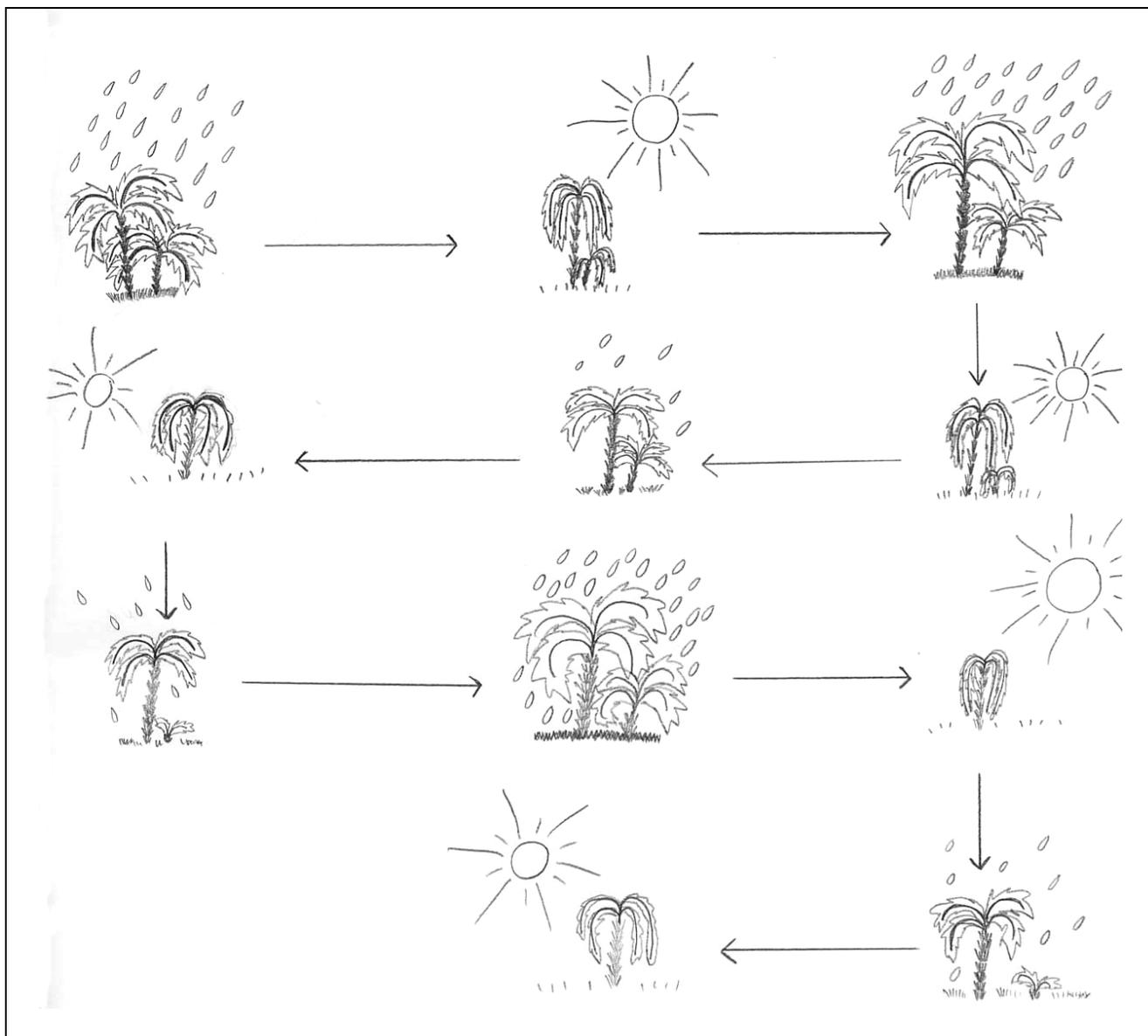


Figure 42: A possible explanation for the sediment progression at the site of Bellevue using Aw-climate.

By definition, a tropical Aw climate has one wet and one dry season per year, which corresponds to one set of conglomerate couples with one set of finer sediment at Bellevue. According to this definition, Bellevue can be seen to represent six years worth of sediment, thought not necessarily directly consecutive. As has been described elsewhere, a major drought took place before year four (see *Unconformities*). It is quite likely that the “untypical” precipitation distribution in year four can be explained as a reaction to the year of drought. The natural balance might not yet have been fully reached. Table 7 shows the vertical progression of sediments in a given year.

Table 7: The sediment progression at the site of Bellevue and its possible depositional timeframe.

Year	Sediment progression
1	conglomerate, packstone
2	conglomerate, packstone
3	grainstone, packstone
4	grainstone, sandstone, conglomerate, mixture between grainstone and packstone
5	mixture between grainstone and packstone, packstone
6	grainstone, packstone

I have used the definition of the Aw-climate in such a way that a combination of the two sedimentological endmembers (i.e. conglomerate and packstone) represents a ‘classical’ Aw-sediment yield for one year, as exemplified by years one

and two. I have decided to do this, because the difference in grainsize between grainstone and packstone seems far too unpronounced for the precipitation difference between the dry and the wet season of a tropical climate. Also, the assumption I have made stands in accordance with the findings of the First Congress of Paleontology at Quillan (1997). If years one and two are interpreted as regular Aw-climate years, with the precipitation occurring during conglomerate deposition, it follows that years three and six represent years with less than average annual precipitation. Years four and five mark a discontinuity with the 'regular' climate pattern. In year four some precipitation occurred before the actual wet season. This would explain the existence of a grainstone and a sandstone deposit before the conglomerate. In contrast, year five was a dry year, maybe even without any precipitation at all. If the deposits for year four and five are directly consecutive, the mixture of grainstone and packstone at the beginning of this year should be interpreted as the continuation of sediment transport at a higher river stage rather than a new phase of precipitation. The attempt to reconstruct the precipitation patterns for the fossilised years at Bellevue is shown in figures 43 through 45.

The question of why we do not see grainstone or sandstone in a typical year at Bellevue, is an interesting one. Apparently the water current was strong enough to deposit conglomerate, but to keep smaller particles such as sand in constant saltation or even in suspension. In contrast, at the beginning of year four, the water force of the river was strong enough to carry what was later to become grainstone and sandstone, but was not yet strong enough so transport the conglomerate. Highest attention has to therefore be given to the intervals of transition.

The difference in precipitation of the wettest and driest month with the least and the most precipitation respectively at Caeitité is 2,8 cm. I interpret this as the time when the water is too slow to deposit conglomerate, but too fast to settle out grainstone or sandstone. The second lowest wet month minus the dry month that shows the highest precipitation equals 4,8 cm. This could be the additional precipitation needed to carry conglomerate. The difference between this number and the previous one equals 2 cm. I interpret this range as the additional water force needed to settle what would become grainstone and sandstone. I am allocating 1 cm of precipitation for both of them.

If this pattern is applied to the precipitation curve of Caeitité, then the following annual precipitation curve is obtained for year four. For convenience I have decided to start plotting the precipitation of a given year with November, because this marks the beginning of the rain season. Figure 43 shows the precipitation pattern for year four.

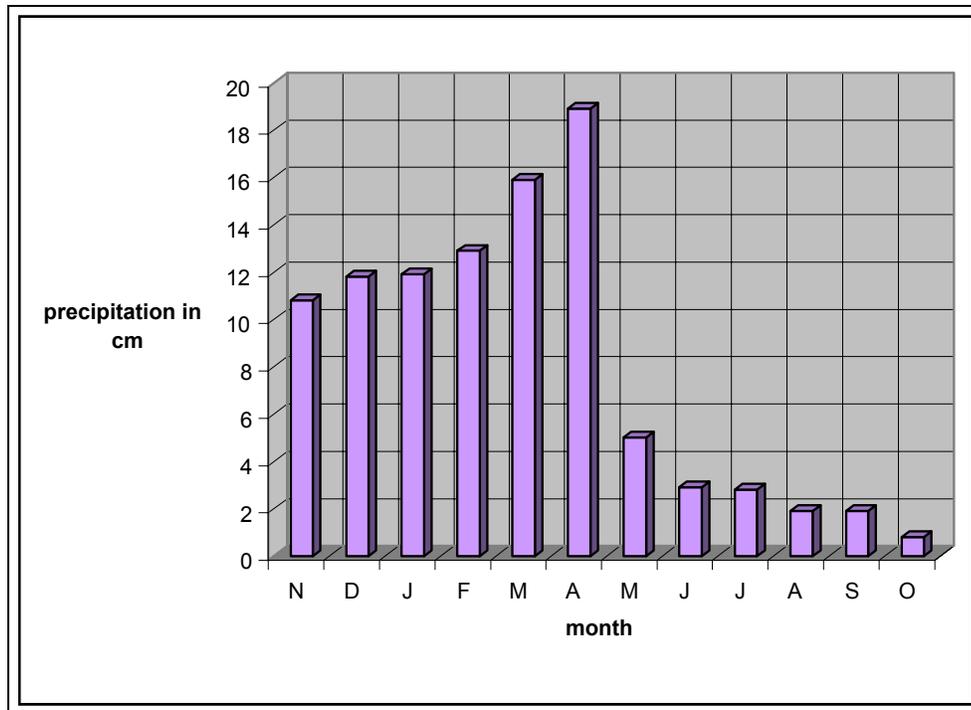


Figure 43: Reconstructed annual precipitation for year four.

The year following year four is also characterised by the mixture of grainstone and packstone at its beginning. This has to be interpreted partially as the swelling off of the particular precipitation distribution in the year before, and partially as the occurrence of a rather dry year, if the deposits are directly consecutive. The precipitation of year five might have looked similar to the one shown in figure 44.

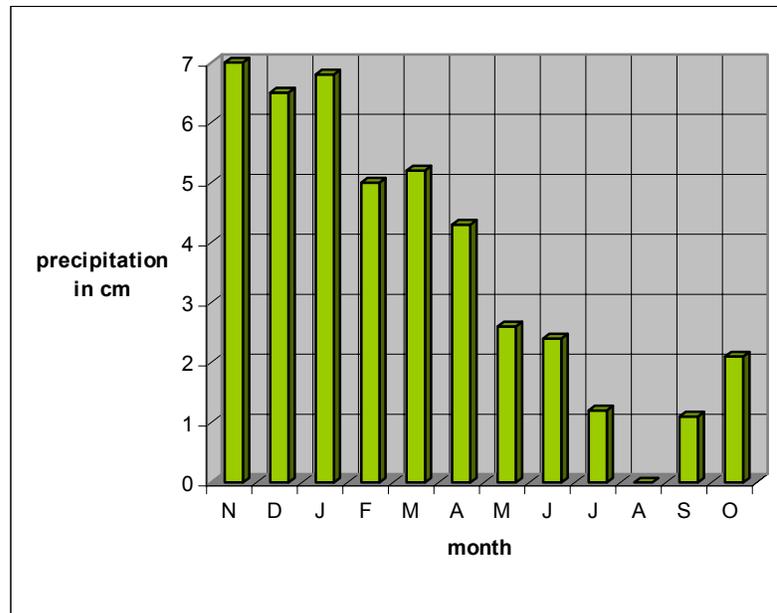


Figure 44: Possible precipitation distribution during year 5.

For the year made of grainstone and packstone, I obtained the following picture:

Because the grainstone replaces the conglomerate found in a 'typical' year, it can be inferred that these must have been years with less than average annual precipitation.

Since the deposition of what would later become grainstone is also in a rather narrow range of water force, it can furthermore be inferred that the precipitation during the wet season of those years must have been fairly similar. Figure 45 shows an approximation to the annual precipitation of the grainstone/packstone years.

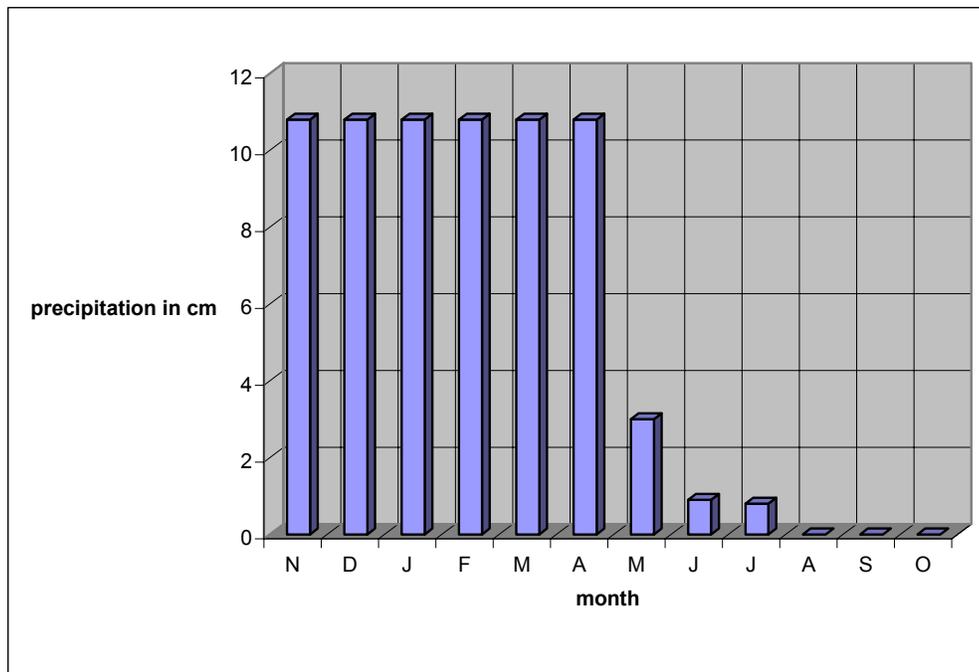


Figure 45: Graph showing the approximate annual precipitation for years 3 and 6 at Bellevue.

It has to be emphasised that the shape of the graphs carries the significant information, not the numbers.

A slightly different way to interpret the gradual loss of conglomerates the further up we go stratigraphically, is to follow Ina Groebke's (2001) hypothesis about a floodplain environment that gradually changed from being fluvial to more lacustrine.

Hypothesis 2 – Storm events

Although there can hardly be any doubt that the climate Eva lived in was tropical, it need not necessarily have been a tropical wet-dry climate. One of the greatest difficulties in working with the stratigraphy at Bellevue is the conglomerates. They vary in shape, size, lateral and vertical dimensions. It is not known how many of

them are lenticular or continuous. Figure 46 shows how heavy and isolated storm events interfere with a fairly 'uneventful' tropical precipitation pattern.

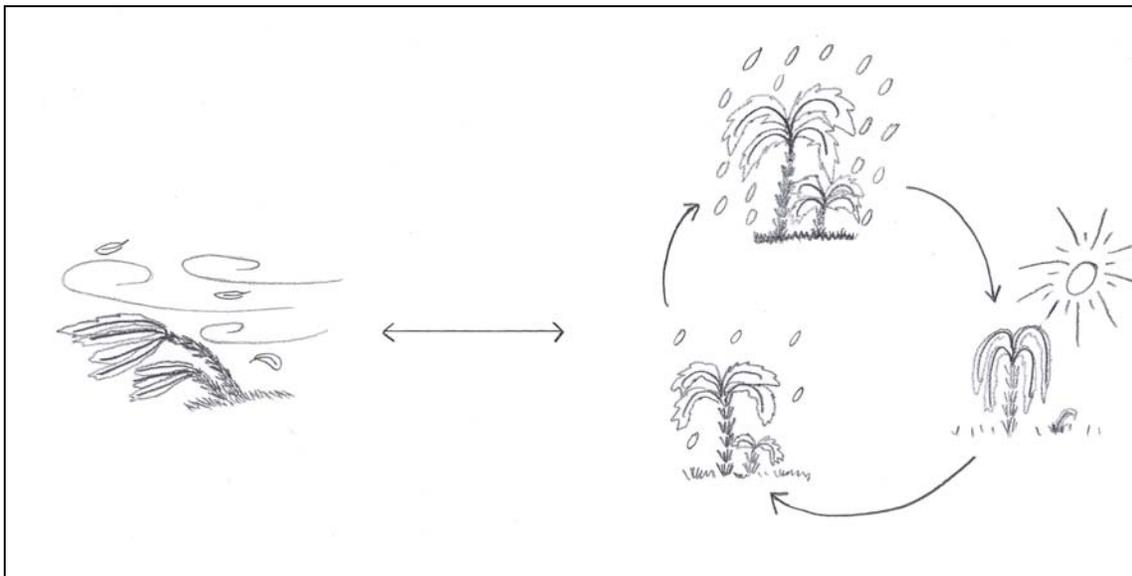


Figure 46: Heavy storm events interfere with a typical tropical climate/precipitation pattern.

The second hypothesis explores the possibility of recurring major storm/flood events that could have been responsible for the existence of the conglomerates and operates on the basis of models done on climatic developments during the Late Cretaceous. There are a couple of possibilities.

1. Every conglomerate present at Bellevue could be the last storm event of a storm season. Every storm could have been strong enough to wipe away the traces of the previous one. Apart from the erosional surface, this model would require another major unconformity right after the sandstone, so that it did not get washed away by the forces of the beginning storm season. Modern storm frequency analyses in the

tropics (Saunders & Rockett, 2001; McNoldy, 1998-2002) show that a typical storm season of about 20 storm events of different magnitudes covers about half a year. The time represented by the sediment would thus be similar to the Aw-climate model discussed under Hypothesis 1.

2. Bellevue could represent a very continuous deposition, at unknown rate, of every single event that occurred during the time frame it represents. This would amount to seven major storm events taking place in an Af or Am type climate.

3. It is possible that only the odd event got fossilised. This would require major unconformities to be present virtually after every sediment layer. If only major catastrophic events got fossilised, every strata at Bellevue, including the packstone, must be seen as somehow related to a storm event.

4. Since interannual storm variability (Anderson & Stern, 1999) is very high, the truth might be a mixture between all of these possibilities.

Hypothesis 3- lateral migration of the river

Figure 47 shows how the stratigraphy at Bellevue could have been caused by continuous lateral migration of the river.

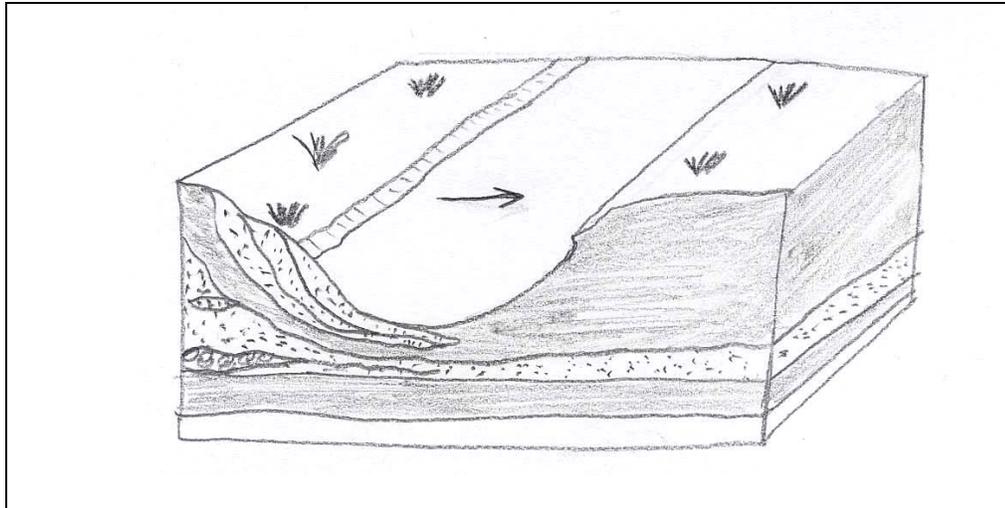


Figure 47: What if the stratigraphy at the site of Bellevue merely represents the complex lateral migration of the ancient meander? This is another hypothesis that has to be taken into consideration.

There exists the possibility that Eva's climate was a "regular" tropical climate with no particular major events and with no major fluctuations in annual precipitation. In this case, the conglomerates could represent reworkings of previously deposited material and stages of a laterally migrating river. Since the site of Bellevue is only slightly above the Grès des Estous Formation, mixing between this sandstone and the superimposed marly deposits might have occurred at the contact zone.

The most likely hypothesis

There are two of reasons for why Hypothesis 1 seems very likely:

1. If Bellevue represents solely a storm-governed system, the high abundance of well-preserved bones is hard to explain. If the storms were violent enough to transport large amount of coarse-grained material within a very

short timeframe, how could the force of the storms have preserved comparatively delicate skeleton parts? If transport distances were generally very low, the preservation of nearly undamaged skeletal material is entirely possible. This, however, raises the question of how a storm has to interact with the surficial geologic features in order to understand how the bones could still be so well preserved.

2. If Bellevue represents only a record of odd events, how can the frequent alternation between a floodplain and a main river channel deposit in the Haute Vallée de l'Aude be understood? Shouldn't the "normal" cycle of depositions be somewhat reflected in the geologic record?

However, any conclusions about paleoclimatology are necessarily inaccurate. Even if the site of Bellevue represents a glimpse into an ancient Aw-type climate, lateral migration of the river and storm events would certainly have been other influencing factors. The true answer, as so often, lies somewhere in between.

Approaching the dimensions of the old river or crevasse splay

In order to attempt to reconstruct the old river dimensions, I have reconstructed the minimum discharge value of the river by a set of models. These models do not meet the standards of models used in similar studies, both, due to a lack of resources and due to a lack of time. It therefore has to be emphasised that my results contain errors that might be fairly large. Nevertheless, this study was a good first step to make.

Approach

It is very likely that the juvenile dinosaur drowned because the forces of the river were stronger than her, thus pushing her over and then transporting her for a short distance to the place of her fossilisation, either a crevasse splay deposit on a floodplain or towards the margin of the main channel of the river, such as a point bar deposit.

Approximations to a discharge value of the river, have been made with eight dinosaur models, which were inserted into a mapped section of Spring Creek (see Appendix 2). These models reflected the same weight distribution, but varied with respect to their filling (density) and slightly in size. The weight distribution was obtained from studies done on *Diplodocus*, which show that 78% of the weight sits in the hindlimb section of the sauropod (Dinosaur Database, 2002). All sauropods were very similar to each other, but anatomical studies (Carrano, 2001) suggest that *Diplodocus* was one of the closest relatives to titanosaurs. Often the head is the only key to differentiating one species from another (Trivedi, 2001).

I have decided to treat the tail and the neck of a sauropod as very similar on an anatomical level. Both of them are made up of vertebrates of decreasing size and the head is small enough to be neglected for weight-based anatomical studies (Laurent, 2002). It can be assumed that the neck and the tail roughly weighed the same. Adding the forelimb section to the neck renders the tail insignificant in terms of weight and fits into the hypothesis that it was primarily used for balance (Gertsch, 1994). Table 8 shows the weight distribution I applied to my models.

Table 8: Different dinosaur body parts versus the % weight distribution.

Part of dinosaur	% weight
Tail	2
hindlimb section	78
front part	20
Total	100

Because it cannot be known whether Eva entered the river or crevasse splay with her neck immersed or not before she drowned the models were inserted into Spring Creeks in these two different ways. The models tipped over at different places. This method yielded a ‘critical area’ for which the local discharge was calculated. This small section of the mapped Spring Creek area represented a percentage of the total average discharge. From these values I calculated the actual discharge values for the site of Bellevue.

Model construction and fieldwork

I built a total of eight models, which are distinguished by their fillings, and fall into two different categories (figure 48). Four models were filled with hard and grainy materials of different sizes: pebbles, rice, great northern beans and sand. The other four models were filled with soft and compressible materials of different consistencies: tofu, jelly, dough and marshmallows. For the model construction, I used aluminium foil, tape, and plastic knives.

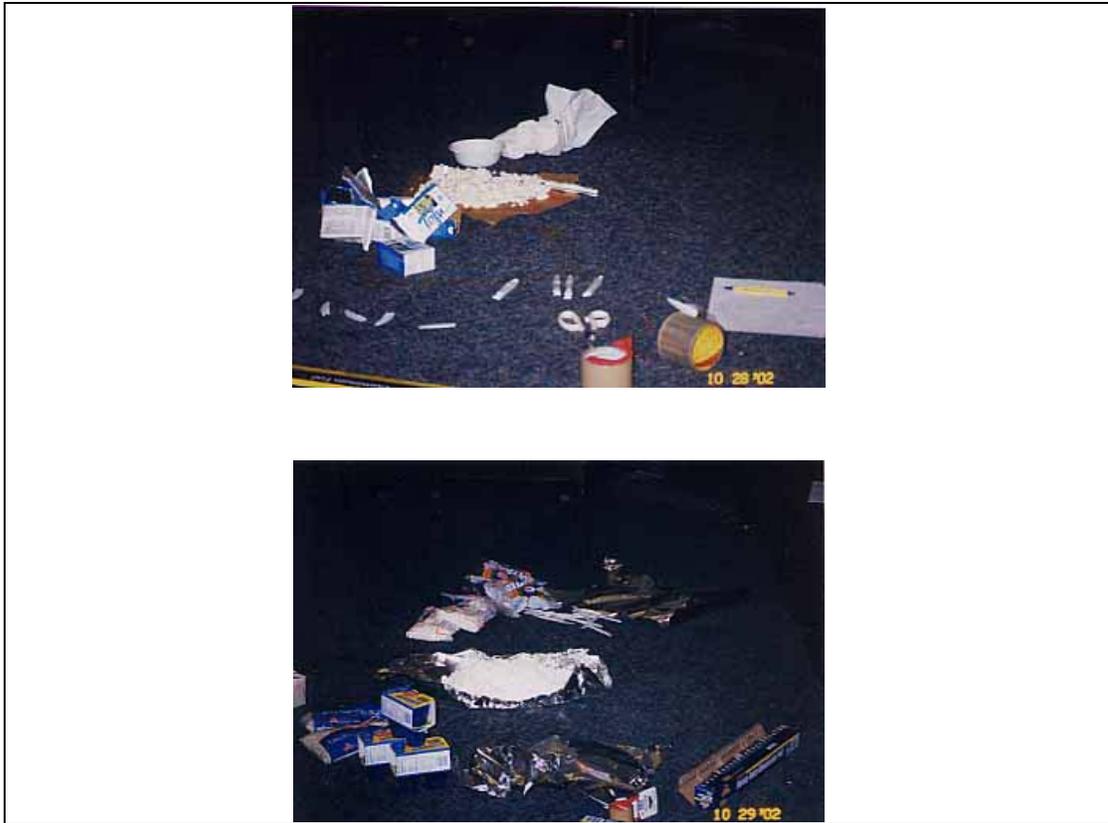


Figure 48: Model construction.

Figure 49 shows one of the completed dinosaur models. The cross-sections of the parts of Spring Creek I worked with can be found in the appendix. Figure 50 shows photographs of the section of Spring Creek I decided to work with. I used a 1.5 m long ruler to span across the creek section and then gradually inserted the models further into the water.



Figure 49: The pebble model.

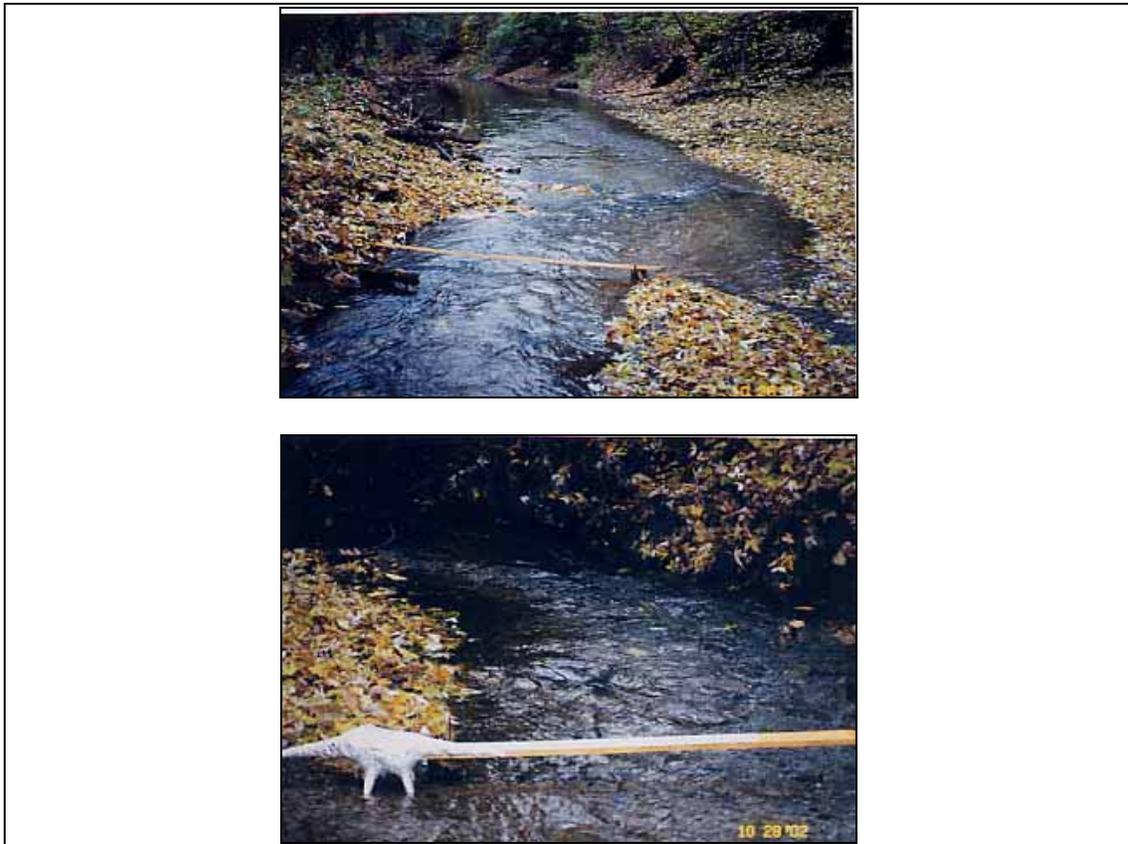


Figure 50: The section of Spring Creek I worked with.

I placed the models into the creek, by slowly inching them forward along the ruler spanning across the section of the creek (figure 50). When the model began to tip, I recorded the distance travelled from the bank, repeated the insertion a couple or times, and then repeated the experiment with a different position of the neck.

Table 9 contains all the calculations that I used for the reconstruction of the ancient river. For the sake of simplicity, I decided to work with the basic equation for discharge values. Since it cannot be known whether or not Eva entered the river or crevasse splay with her neck above the water or immersed into the water, I obtained a slightly larger value for the regional width, than I would have, had I assumed one of the cases only.

Table 9: The calculation of the discharge value for every model.

Discharge $Q = w \times d \times v$; where w stands for width, d for depth and v for velocity.

Bean model

weight: 1.05177 kg;
 regional width: 22 cm – 18 cm = 4 cm;
 average regional depth: 5.75 cm;
 average regional velocity: 0.11 m/s;
 Spring Creek average discharge: 0.048 m³/s;
 Partial discharge for the area in which the model tipped:
 $Q = 0.04 \text{ m} \times 0.0575 \text{ m} \times 0.11 \text{ m}^2/\text{s} = 0.000253 \text{ m}^3/\text{s}$; (this value equals about 1% of the Spring Creek average discharge)

0,000253 m³/s is to 1.05177 kg as 2.40 m³/s is to 10000 kg.

2.40 m³/s is 1% of the total average discharge of the ancient river.
 Total average discharge $Q = 240 \text{ m}^3/\text{s}$.

Sand model

weight: 1.10563 kg;
 regional width: 16 cm – 10 cm = 6 cm;
 average regional depth: 5.4 cm;
 average regional velocity: 0.09 m/s;
 Spring Creek average discharge: 0.048 m³/s;
 Partial discharge for the area in which the model tipped:
 $Q = 0.06 \text{ m} \times 0.054 \text{ m} \times 0.09 \text{ m}^2/\text{s} = 0.0002916 \text{ m}^3/\text{s}$; (this value equals about 1% of the Spring Creek average discharge)

0.0002916 m³/s is to 1.10563 kg as 2.64 m³/s is to 10000 kg.

2.64 m³/s is 1% of the total average discharge of the ancient river.
 Total average discharge $Q = 264 \text{ m}^3/\text{s}$.

Rice model

weight: 1.168 kg;
 regional width: 31.5 cm – 30 cm = 1.5 cm;
 average regional depth: 0.09 cm;
 average regional velocity: 0.26 m/s;
 Spring Creek average discharge: 0.048 m³/s;
 Partial discharge for the area in which the model tipped:
 $Q = 0.015 \text{ m} \times 0.09 \text{ m} \times 0.26 \text{ m}^2/\text{s} = 0.000351 \text{ m}^3/\text{s}$; (this value equals about 1% of the Spring Creek average discharge)

0.000351 m³/s is to 1.168 kg as 3.005 m³/s is to 10000 kg.

3.005 m³/s is 1% of the total average discharge of the ancient river.
 Total average discharge $Q = 300.51 \text{ m}^3/\text{s}$.

Pebble model

weight: 1.842 kg;
 regional width: 54 cm – 50 cm = 4 cm;
 average regional depth: 15.35 cm;
 average regional velocity: 0.44 m/s;
 Spring Creek average discharge: 0.052 m³/s;
 Partial discharge for the area in which the model tipped:
 $Q = 0.04 \text{ m} \times 0.1535 \text{ m} \times 0.44 \text{ m}^2/\text{s} = 0.0027016 \text{ m}^3/\text{s}$; (this value equals about 5% of the Spring Creek average discharge)

0.0027016 m³/s is to 1.842 kg as 14.66 m³/s is to 10000 kg.

14.66 m³/s is 5% of the total average discharge of the ancient river.
 Total average discharge $Q = 293.5 \text{ m}^3/\text{s}$.

Table 9 continued.

<p>Tofu model</p> <p>weight: 2.055335 kg; regional width: 41 cm – 35 cm = 6 cm; average regional depth: 0.105 cm; average regional velocity: 0.27 m/s; Spring Creek average discharge: 0.048 m³/s; Partial discharge for the area in which the model tipped: $Q = 0.06 \text{ m} \times 0.105 \text{ m} \times 0.27 \text{ m/s} = 0.001701 \text{ m}^3/\text{s}$; (this value equals about 3.5% of the Spring Creek average discharge)</p> <p>0.001701 m³/s is to 2,055335 kg as 8,27 m³/s is to 10000 kg.</p> <p>8,27 m³/s is 3.5% of the total average discharge of the ancient river. Total average discharge $Q = 236.29 \text{ m}^3/\text{s}$.</p> <p>Marshmallow model</p> <p>weight: 1.78886 kg; regional width: 82 cm – 47 cm = 35 cm; average regional depth: 14.7 cm; average regional velocity: 0.36 m/s; Spring Creek average discharge: 0.048 m³/s; Partial discharge for the area in which the model tipped: $Q = 0.35 \text{ m} \times 0.147 \text{ m} \times 0.36 \text{ m/s} = 0.0185 \text{ m}^3/\text{s}$; (this value equals about 38% of the Spring Creek average discharge)</p> <p>0.0185 m³/s is to 1.78886 kg like 103.42 m³/s is to 10000 kg.</p> <p>103.42 m³/s is 38% of the total average discharge of the ancient river. Total average discharge $Q = 272.16 \text{ m}^3/\text{s}$.</p> <p>Jelly (Wacky Gels) model</p> <p>weight: 1.06594 kg; regional width: 24 cm – 20 cm = 4 cm; average regional depth: 0.06 cm; average regional velocity: 0.11 m/s; Spring Creek average discharge: 0.048 m³/s; Partial discharge for the area in which the model tipped: $Q = 0.04 \text{ m} \times 0.06 \text{ m} \times 0.11 \text{ m/s} = 0.000264 \text{ m}^3/\text{s}$; (this value equals about 1% of the Spring Creek average discharge)</p> <p>0.000264 m³/s is to 1.06594 kg as 2.48 m³/s is to 10000 kg.</p> <p>2.48 m³/s is 1% of the total average discharge of the ancient river. Total average discharge $Q = 248 \text{ m}^3/\text{s}$.</p> <p>Flower Dough model</p> <p>weight: 2.10637 kg; regional width: 36 cm – 27 cm = 9 cm; average regional depth: 10.25 cm; average regional velocity: 0.20 m/s; Spring Creek average discharge: 0.048 m³/s; Partial discharge for the area in which the model tipped: $Q = 0.09 \text{ m} \times 0.1025 \text{ m} \times 0.20 \text{ m/s} = 0.001845 \text{ m}^3/\text{s}$; (this value equals about 4% of the Spring Creek average discharge)</p> <p>0.001845 m³/s is to 2.10637 kg as 8.76 m³/s is to 10000 kg.</p> <p>8.76 m³/s is 4% of the total average discharge of the ancient river. Total average discharge $Q = 219 \text{ m}^3/\text{s}$.</p>

Data Analysis

As can be seen from my calculations, all the average discharge values obtained for the ancient river are close to each other in magnitude. Therefore, it seems that an accurate weight distribution is more important than the densities of the materials used for the model construction. The reason for this shall be left to physicists. The average value for the discharge of Eva's river or crevasse splay equals $Q = 259,18 \text{ m}^3/\text{s}$. The sand model reflects this value best, having yielded a discharge of $Q = 264 \text{ m}^3/\text{s}$.

Do fine, grainy materials lend themselves best for models reflecting accurate weight distribution? Does sand in particular reflect the weight and density properties of bones and flesh very well? These questions shall be left for further studies.

As I have stated, it is possible that Eva died in the main channel of a river (see figure 51).

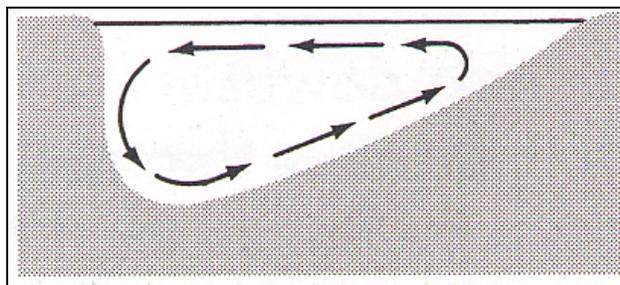


Figure 51: A typical meander channel profile (from Ritter, Kochel, Miller, 1978). Could Eva have died in the deepest and fastest part of the channel?

The current of the water in Spring Creek generally affected my models three quarters up their full height. Since Eva was not yet fully grown, I estimate that a

minimum water depth of 2 m should have had an effect on her. This estimation is based on the Dinopedia webpage (2002), which lists the average adult height for titanosaurs as 5-6 m. Could a depth of 2 m have been in the deepest part of the channel? If Eva did indeed drown within the main channel of the river, it is likely that the width of the river was greater than her. She measured 15 m in length. These are all the approximations that can be made.

Reconstruction of the Paleoecology

An exact paleoecological reconstruction of Bellevue is impossible (McKone, 2002). An approximation is nevertheless very valuable to make, be it because of its methods, results or even its mistakes. The paleoecological reconstruction in this study is primarily aimed at the nutrition-based interaction between all the animals present at the site, at the daily food intake of different species, as well as at approximating the ancient vegetation and population density. Table 10 summarises the paleoflora and the paleofauna at the site of Bellevue and figure 52 shows how the members of the paleoecology interacted with each other.

Table 10: Summary of paleofloral and paleofaunal remains found at the site of Bellevue (after Bilotte, Koess & Le Loeuff, 1999).

<i>Plants</i>
<ul style="list-style-type: none"> •cycads •plams
<i>Invertebrates</i>
<ul style="list-style-type: none"> •gastropods •bivalves
<i>Vetrebrates</i>
Fish
<ul style="list-style-type: none"> •Osteichtyes Lepisosteidae Lepisosteus sp. (Bonefish)
Tortoises
<ul style="list-style-type: none"> •Chelonia indet.
Crocodyles
<ul style="list-style-type: none"> •Eusuchia Allodaposuchus precedens •Mesosuchia Trematochampsidae Ischyrochampsia meridionalis
Dinosaurs
<ul style="list-style-type: none"> •Sauropoda Titanosauridae Ampelosaurus atacis •Theropoda Dromaeosauridae Variraptor mechinorum •Ornithopoda Iguanodontia incertae sedis Rhabdodon priscus •Thyreophora Ankylosauria indet.
Pterosaurs
<ul style="list-style-type: none"> •Pterosauria indet.
Birds
<ul style="list-style-type: none"> •Gargantuavis philoinos (running bird)

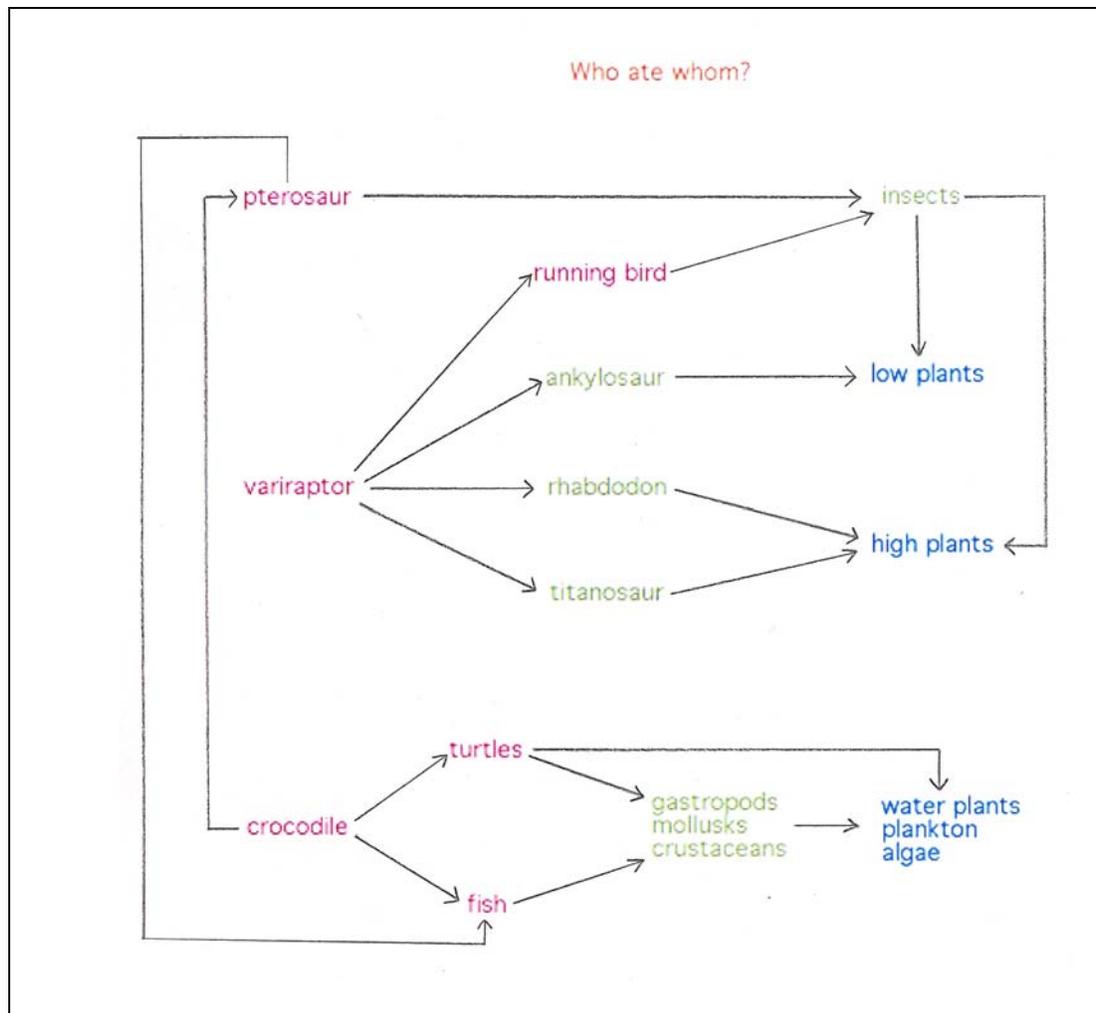


Figure 52: Who ate whom? The red words indicate carnivores, the green ones herbivores and the blue ones represent plants or low members of the food chain.

Population density depends, among other variables, on available food sources. How much did the animals at Bellevue eat every day? The persistent lack of literature on trends in daily food intake of animals is remarkable. The approximations in the following study are made by myself, and reflect two points, which crystallised during my personal correspondence with an animal physiologist (Rand, 2002): a) Animals during growth require slightly more food than the adults of the same species; b) a

small animal eats about 2% of his/her body weight every day. When a certain size is reached, this function decreases in a non-linear way.

For information on the food-weight relationship in living animals, several works on animal physiology have been reviewed (Benedict, 1870; Camel Information; Gauthier-Pitters & Dagg, 1981; Burns & Montague & Cowles, 1993; Zann, 1996). The approximations for the daily food intake and the weight for the animals used in this study can be found in table 11. Figures 53 and 54 show the resulting graphs based on this table.

Table 11: The body weight, weight of daily food and percentage of body weight consumed every day.

Animal	body weight	amount of daily food	% of body weight eaten daily
Mouse	100 g	2 g	2
Zebra finch	200 g	4 g	2
my cat	1500 g	30 g	2
Golden Retriever	38 kg	700 – 800 g	2
Human	70 kg	1- 2 kg	2
Camel	700 kg	11 kg	1,5
Elephant	3000 kg	39,32 kg	1,3
Whale	120000 kg	130 kg	0,011

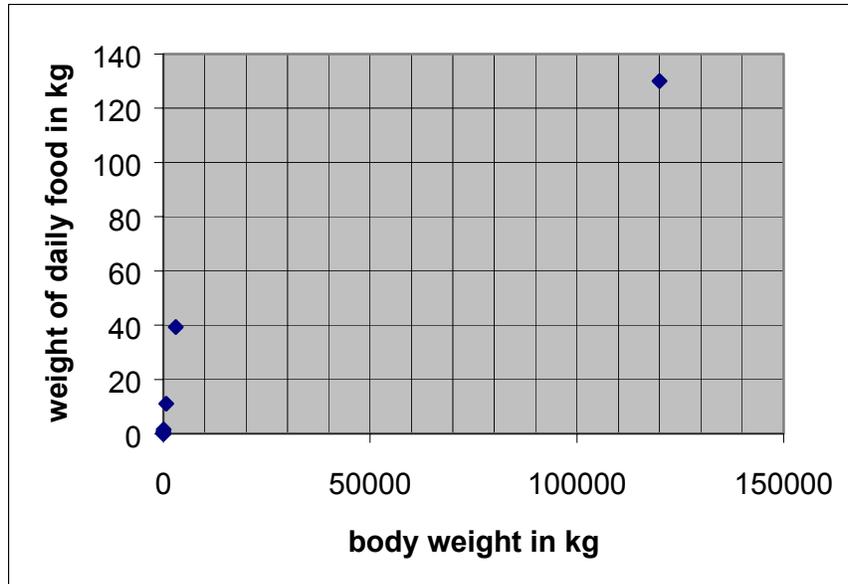


Figure 53: Scatter graph showing the relationship between body weight and the weight of the food eaten every day.

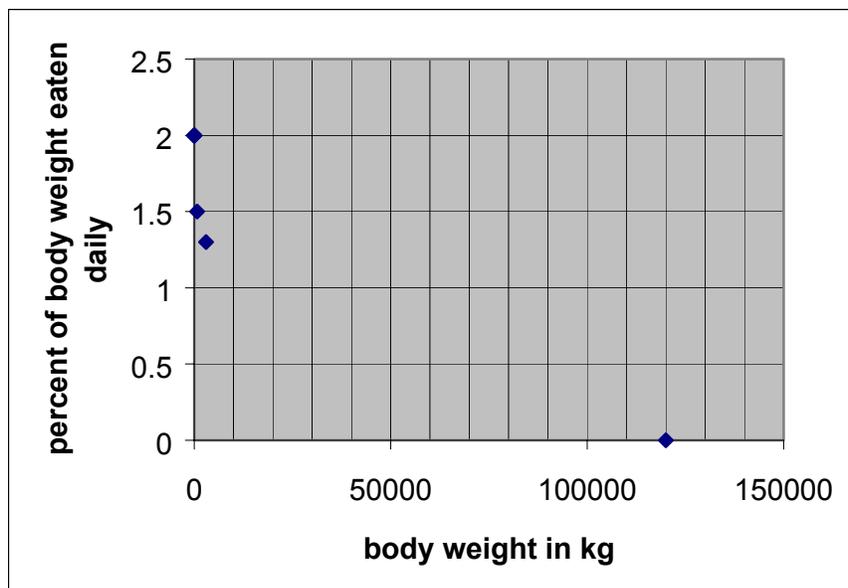


Figure 54: Scatter graph approximating the non-linear decrease of the percent of the body weight eaten every day and the body weight.

Although I have not found more useful data for these graphs, it can be discerned that their shape approaches an exponential function. The functions I picked for my calculations are supported by two biologists (Singer and Rand, 2002). Table 12 shows the daily food intake for the fauna at Bellevue.

Table 12: (The numbers for the body weights were obtained from the following sources: Gielewski, 1999; New Zealand Ostrich Association, 2002; Crocodile Information; Pteranodon Information; Rodgers & Rodgers, 2001; Busch Gardens Animal Information Database, 2002; Head, 1998; Le Loeuff & Buffetaut, 1998; Enchanted Learning Software, 1996-2001.)

animal	body weight	weight of daily food
Eva (adolescent titanosaur)	10000 kg	80 kg
Rhabdodon	400 kg	8 kg
Variraptor	50 kg	1 kg
Ankylosaurus	3500 kg	42 kg
Pteranodon	16 kg	0,320 kg
Crocodile	980 kg	13,72 kg
Running Bird	30 – 100 kg	0,600 – 2 kg
Turtle	2 – 3 kg	0,040 – 0,060 kg
Bonefish	4 kg	0,080 kg

The reconstruction of the paleoecology is based only on the fossil record present at Bellevue. It does not take into account the possible faunal member that could have been present at Bellevue but did not get fossilised.

Reconstruction of the land ecology

Daily amount of food for herbivorous dinosaurs

Data collection for the weight of different kinds of foliage has been carried out by Cyril Davies (2002) for different plants found in southern Andalusia. 30 samples of each, *Phoenix canariensis* and *Chamaerops humilis* were randomly selected. Figure 55 shows pictures of both these species.

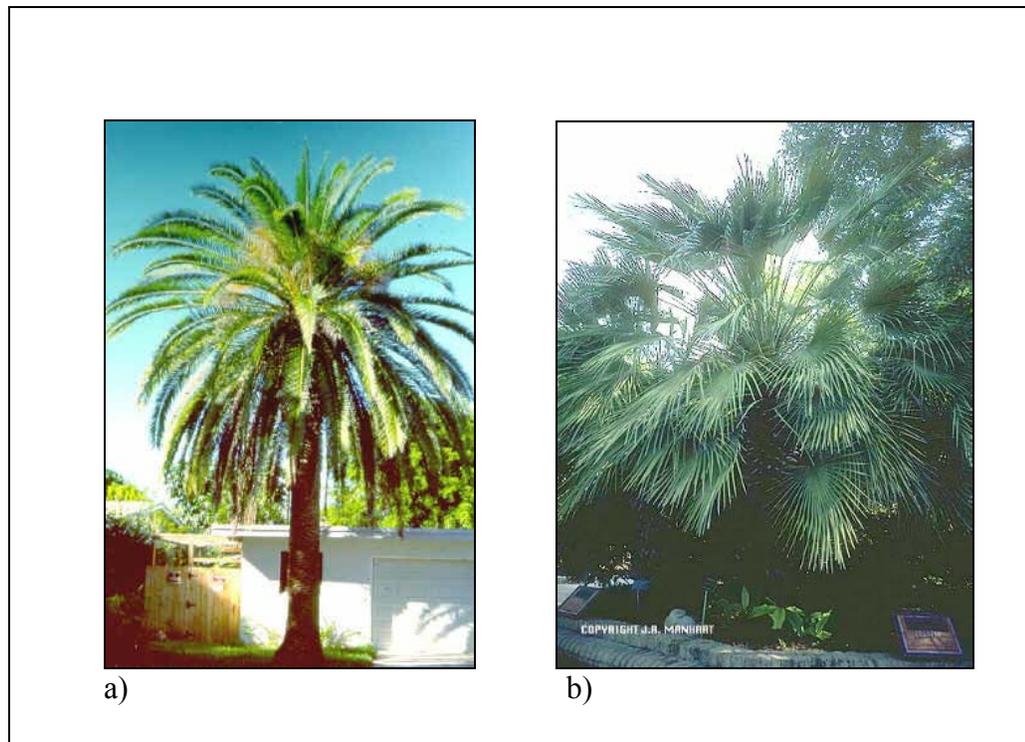


Figure 55: a) *Phoenix canariensis*; b) *Chamaerops humilis* (Pictures taken from Palm & Cycad Society of Florida, 1998-2001.)

For *Phoenix canariensis* the average weight for one branch lies around 1700 g and there are about 40 branches per palm. The average weight per branch for *Chamaerops humilis* is 50 g, and there are about 120 branches per tree. In addition, six different species of fern were sampled (10 times each). The average weight for one fern leaf amounted to 5 g, and the average number of branches per fern plant was 12. Figure 56 shows the types of branches that were collected and weighed in southern Andalusia.



a)



b)



c)



d)

Figure 56: a) shows a branch of *Chamaerops humilis*;; b) shows a branch of *Phoenix canariensis*. An ordinary kitchen scale was used to determine the weights of the individual fern and palm branches (c). The handy in the picture in d) measures about 10 cm in length.

This type of data collection has also been carried out by myself for different types of conifer trees. In my sample of 50 trees I found the average number of branches to lie around 66. Age and species differences are reflected in this number. The addition of conifers to my model rendered it too complex. I was unable to find any substantial research done on the effects of defoliation on conifer trees. Therefore, I have left them out, regarding their addition as a big source of error.

For the sake of simplicity, I have limited my analysis to three plants: High palms, medium high palms and ferns. I have assumed that a titanosaur would have eaten high plants, a rhabdodon medium high plants and an ankylosaurus low plants, because of their respective body heights. A titanosaur would have required 1.2 *Phoenix canariensis* per day, amounting to 438 trees per year. A rhabdodon would have eaten 1.3 *Chamaerops humilis* per day, or 474.5 trees per year. An ankylosaurus would have required it 700 fern plants every day, or 255500 ferns per year.

Daily amount of food for carnivorous dinosaurs

Many studies (e.g., Keesey, 2001) suggest that variraptors hunted in packs. The size of these packs is not clear. Wolves are often used as an analogy. Pack sizes of wolves usually include six or seven members (Wolf Web, 1999-2001). For this study, I have worked with a variraptor pack size of six.

Because of its marvellous protection, it is unlikely that small carnivorous dinosaurs could have done any serious damage to an ankylosaurus. It is believed that ankylosaurs were solitary animals, and would therefore have been less visible in the paleoecology. I have limited the food choice of variraptors to titanosaurs, rhabdodons

and running birds. Mathematically, a titanosaur would have fed six variraptors for well beyond their life times, a rhabdodon would have sustained them for about 66 days, and a running bird would have lasted for five to 16 days. These calculations are not realistic, because the decomposition rate in the tropics is very high. After a couple of days, the meat would have been spoiled. Observations of the decomposition rate of shot elephants (Priore, 2002) shows that the carcasses can disappear within a week, without any major carnivorous activity. I have therefore assumed that a group of six variraptors must have killed about once every week, assuming a mixture of prey size. This reflects the hunting behaviour of many carnivorous animals today, and also is quite energy efficient. A possible annual diet of six variraptors, with maximal variety, could have roughly consisted of 17 titanosaurs, 17 rhabdodons and 18 running birds.

The base population

Without considering a family factor that would ensure further survival, the base population, i.e. one pack of variraptors, their prey and the prey's food for one year, consists of six variraptors, 17 titanosaurs, 17 rhabdodons, 18 running birds, 7446 high trees and 8067 trees of medium height.

Insects must have been plentiful to sustain the running bird. One running bird would have required an average of 730 kg of insects per year (calculation based on table 9). The abundance of flowering plants must have been high, even if they do not appear anywhere in the fossil record at Bellevue. Ferns must have also been abundant enough to nourish the few ankylosaurs present.

Spatial considerations for the land population and vegetation

The "large body size effect" and vegetation density

The most important factor that governs tree density in Eva's ecology is the effects of migrating herds of herbivorous animals with huge bodies through woodlands. Profound damage can be done to plants by migrating animals with large body sizes. In a study done on the effects of elephant browsing on woodlands (Barnes, 1983), it has been found that 40% of trees were dead during the year of observation and that 67% of the trees had been killed during the previous six years. The tree mortality rate was found to decrease with decreasing tree density. A relatively low tree density would have been an advantage for the survival of the fauna at Eva's times. Hubbell (1979) suggests that low density and uniform dispersion of adult tropical trees is very common. This vegetation pattern apparently has its origin in the fact that herbivores tend to defoliate and kill nearby seedlings rather than distant seedlings when attracted by adjacent adults (Hubbell, 1979). Other studies (Connell, 1978) suggest that low vegetation density and high diversity of plants are only maintained because of frequent disturbance by herbivores.

The hypothesis of a relatively low-density, but nevertheless rich, vegetation is supported by findings on dinosaur migratory behaviour (Martin, 2001). All the herbivorous dinosaurs are thought to have migrated a lot, and sauropods especially have a long history in ichnology (Martin, 2001). However, any conclusions about forest dynamics are necessarily tentative because even modern studies are based on the circumstantial evidence provided by one census at a single point in time.

Palm growth and consequences of defoliation

My calculation results in the previous sections show that the daily food intake by the herbivorous dinosaurs was quite enormous. Defoliation of plants must have been another major effect on the vegetation and on its ability to sustain a given population of herbivorous dinosaurs. How long would it have taken a defoliated plant to restore itself? Most studies that report leaf production rates for palms are based on short-term observations and do not account for the variability over decades (Bannister, 1970; Sarukhan 1978; Savage & Ashton, 1983; Waterhouse & Quinn, 1978). After seven years of observation, Piñero et al., (1984) found different rates of leaf production in three stages of growth of *Astrocaryum mexicanum*. The rates ranged from 1,3 to 2,6 leaves per year. Figure 57 shows pictures of two the two palm species studied by other people.

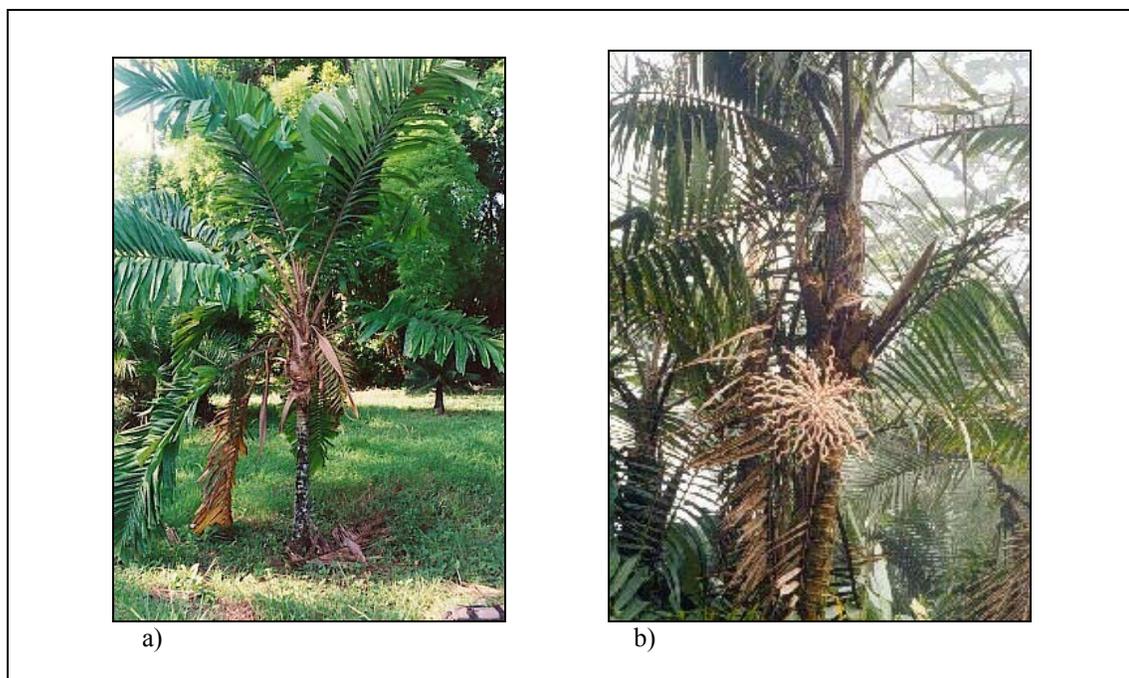


Figure 57: a) *Astrocaryum mexicanum*; b) *Prestoea montana* (Pictures taken from Kyburz, 2002 and Skean, 1990.)

Long-term research (36 years) done on the palm *Prestoea Montana* (Lugo & Rivera Batille, 1987) reveals that the palm family is characterised by incessant leaf production. The research area focused on a 0.4 ha plot in a palm forest located in the subtropical rain forest zone. Growth rates of this sierra palm were found to have the following characteristics: a) The leaf production rates are variable within a single palm. b) There are marked differences in growth rates among palms of the same population. c) Leaf production is highest in dominant palms after they have attained a certain height or age. These values can be as high as 4.6, in some cases 5.6 leaves per year. The average rate of production was found to be 4 leaves per year. Growth rates are very hard to understand and can vary even on the same plant. Figure 58 shows a fossilised palm leaf at the site of Bellevue.

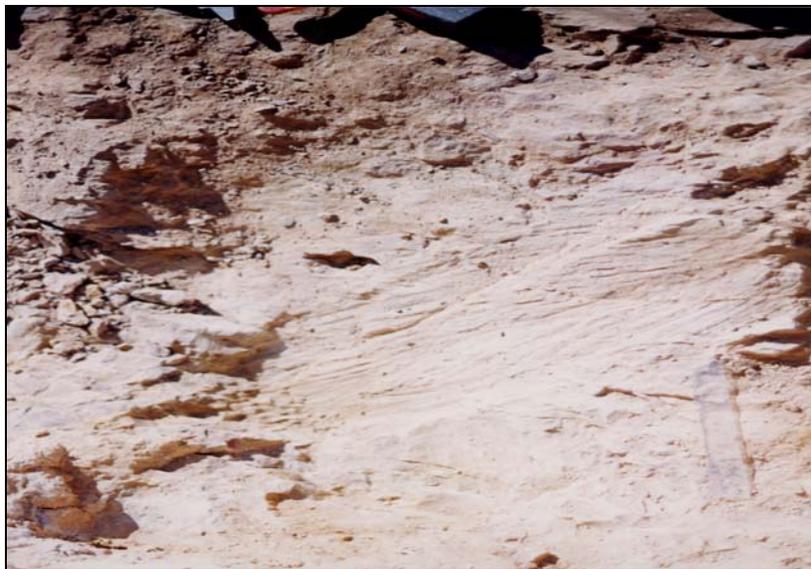


Figure 58: One of the most predominant plants found at Bellevue are palms and cycads (The ruler on the photo is 15 cm long).

The impact of defoliation on plant performance is profound. It is poorly documented for tropical plants, although significant attempts have been made to

understand these faunae (Mendoza, Piñero & Sarukhan, 1987). In their study they found that defoliation had important effects on all age classes of plants. Removal of all leaves had the most severe effects on leaf production in juvenile plants. By contrast, defoliation in old plants increased the production of foliage significantly. In all cases, defoliation had a profound effect on the reproduction potential. 80% of the defoliated trees in a different study (Rockwood, 1973) failed to produce fruits in the year of their defoliation. Restoration after complete defoliation of *Phoenix canariensis* and *Chamaerops humilis* takes 10 and 30 years respectively if an average annual leaf production rate of 4 leaves is assumed.

Ferns

Analogous studies done on ferns (Sharpe, 1993) reveal that the annual leaf growth rate in mature populations lies around 1.6 leaves. A typical fern plant is shown in figure 59.



Figure 59: A common fern species.
(Picture taken from Nicholls, 1998.)

The maximum life span of the sporophyte is estimated to be at least 23 years. Restoration after complete defoliation of a mature plant of all species sampled in Andalusia (Davies, 2002) requires a little more than half its lifetime!

Population density

It is impossible to make any concrete statements about the population density of what is Bellevue today. Population density is based on a number of factors, of which availability of food resources, type of migration patterns, mode of defoliation and tree spacing are only a few. What can nevertheless be done is to construct a simple model that shows the relationship of population density to time. The following calculations were carried out for completely defoliated plants only, because partial defoliation is very difficult to define. Since the numbers obtained for complete defoliation only have to be modified by a fraction to see what a possible type of partial defoliation could have caused, these calculations are left to the curious reader.

The yearly amount of food for the herbivorous dinosaur population and the leaf growth potential have been stated elsewhere (see *The base population*). The recovering vegetation after complete defoliation would have fed 17 titanosaurs for 37.23 days, 17 rhabdodons for 11.9 days and an ankylosaurus for 48.7 days. These numbers suggest a couple of things: a) the Late Cretaceous must have been a very high-energy environment with respect to population dynamics. b) migration patterns for different dinosaurs were variable. c) the population density most likely varied constantly depending on which food resources were available at a given point in time and how far they were spaced from each other.

Reconstruction of the water ecology

The majority of animals living in the ancient river were carnivorous. Both turtles and bonefish are relatively negligible in terms of their daily food intake, since they would have fed on small invertebrates that are always plentiful in healthy fresh aquatic settings.

It is not clear from the fossil record at Bellevue whether the pterosaur was an insect or a fish eater. Its preservation state is extremely bad, suggesting that it might have flown too closely to the water surface in pursuit of prey and got pulled into the river by a crocodile.

Crocodiles have a very flexible diet. It is very likely that the crocodiles at Bellevue ate whatever lived in the water as well as what came close to the water. An average crocodile requires 13.72 kg of meat daily, which amounts to 5007.8 kg per year. Assuming the most varied diet possible, this number is equal to 105 pterosaurs, 418 bonefish and 668 turtles per year.

Discussion

Chapter One: Sedimentology and Stratigraphy. It could have been the margin of a braided river or a meander, or else, a floodplain influenced by a crevasse splay...Where does the truth lie? It seems that all three hypotheses listed explain the sediment progression at the site of Bellevue satisfactorily to some extent. The model of the braided river explains the stratigraphy at Bellevue because of fast lateral changes in the strata. The meandering river system accounts for the presence of

calcareous nodules and fossilised waterlogged material. The channel or crevasse-splay influenced floodplain explains the presence of sheet-like sands and conglomerates and the high abundance of paleosol facies. The trouble in gaining a clearer view on the nature of the sediments, is that braided rivers are very difficult to distinguish from meandering systems in a set of ancient sediments. Although channel or crevasse splay influence were a major factor in the sediment formation at the site, the strata are fine grained and show characteristics of floodplain deposits. The fact that the present study is merely based on one summer's worth of fieldwork adds fuzziness to the results.

Mineralogy. The solidity of my necessarily tentative conclusion about the depositional environment is furthermore weakened by the lack of knowledge about the source for the mineralogical assemblage at the site of Bellevue. Calcite, quartz, kaolinite, goethite and amorphous silica are the main minerals present at the site. How does the mineral assemblage vary laterally, geographically and vertically in the region? Due to constraints on resources, time and the accessibility of further outcrops in the region of study, I was unable to reach any conclusions on this matter. The Mount Mouthoumet Formation has been suggested as a possible source, but the proof for this hypothesis still remains to be found.

Climate. The conclusion that the Maastrichtian climate of southern France was hot is almost certain. I have listed numerous factors for why a tropical climate setting is the better explanation for the observations made than a semi-arid climate setting. As is shown by the presence of minerals such as kaolinite and montmorillonite, annual precipitation must have been higher than 500 mm per year.

Although precipitation that high can occur in semi-arid climates, it would require high elevations. I have shown that this is not the case for the Maastrichtian Bellevue.

Skeletal remains and Taphonomy. The taphonomical analysis is detailed, but limited. In the past, excavated bones and fossil levels often were not recorded. This lack of data renders impossible a full analysis and interpretation of the vertebrate remains present at Bellevue. The taphonomical study in this report is based upon the bone material unearthed during the excavation in the summer of 2002, and incorporates the findings of Anne Schulp (1995/96) where appropriate. It is important to emphasise that Bellevue has not yet yielded all its bones. Future revision and expansion of the findings presented here therefore is a necessity. Because they are not equally strong, the rose diagrams have to be viewed with caution. Overall, they provide valuable insights into bone and fracture orientations, but the individual diagrams could not be constructed with equal amounts of data, since different fossil levels carry different amounts and different types of vertebrate remains. The experiments carried out with the animal carcasses add a couple of interesting points, but must not be viewed as reliable sources. For example, dissection could have been carried out differently and could have been repeated with different animals.

Eva's Death. My hypothesis about death by drowning is necessarily tentative, yet it seems to explain the presence of features in Eva's bone assemblage and lack of others well.

Chapter Two: My experimental section incorporates studies that all approach a 'question of a lifetime' in a very simplistic way. I am fully aware of this, and of the large sources of error my approach created. Nevertheless, I hold the view that such

experiments and explorations of hypotheses are valuable to do, since they are an important first step to make into future, more elaborate studies on the matters they address. Furthermore, a healthy amount of imagination often yields the necessary spark for creative ideas and inventions. I do not believe I have wildly speculated about what the past could have been like. Instead, I attempted to root the hypotheses I explored scientifically, even if so in a limited way.

Elaborations on Climate. This section shows in great detail that the stratigraphy found at Bellevue might be the result of a combination of seasonal rains, major storm events and the lateral migration of the river. It was found that the seasonal precipitation within a tropical Aw-type climate is most likely the main agent for the stratigraphy found. Because of the sedimentological setting of the Haute Vallée de l'Aude, the lateral migration of the river system is believed to be the second most important factor. Season unrelated storm events cannot be ruled out, but are not seen as a major agent of sedimentation.

Reconstruction of the old river dimensions. Eight weight-based models of Eva were constructed with different materials and inserted into a mapped section of Spring Creek. Calculations of the discharge value for the regions in which the models tipped over revealed that the values all fell into a narrow range. Although this is a positive sign, it has to be understood that model construction was carried out without the application of proper scale modeling. Scale modeling is a challenging and tedious process to undertake that most often involves numerous people. Clearly, this was not the case in the present study, leading to a big source of error.

The reconstruction of the paleoecology. This section was the result of careful work with two members of the Biology Department at Carleton College as well as consultations of animal physiology and plant studies. As all other experimental sections the approach taken to the question addressed was crudely oversimplified, yet my results reflect a reasonable reconstruction of the ecology for the fossil assemblage present at the site of Bellevue during the summer of 2002.

Conclusion

Chapter One. The depositional environment during the Late-Cretaceous in the Haute Vallée de l'Aude was characterised by frequent changes from river channels to floodplains. The strata present at Bellevue were deposited either towards the margins of a braided river, a meandering river system or on a floodplain close to the main channel of the river, influenced by a crevasse splay, and shows characteristics of all three. Further, and more geographically extensive studies are required to clarify the exact nature of the sediments. The paleo-climate was warm, almost certainly a tropical Aw-type climate with distinct wet and dry seasons, resulting in more than 500 mm of annual precipitation. The paleo-ecological setting was found to be very diverse with respect to both, flora and fauna. Numerous remains of palms, cycads, crocodiles, pterosaurs, fish, dinosaurs as well as freshwater invertebrate species (mostly gastropods and mollusks) have been unearthed at the site. The statistically high representation of titanosaur vertebrate remains can be best understood when considering the preferred living environment of sauropod dinosaurs, which is in proximity to rivers. The fossil assemblage at Bellevue is allochthonous with the

exception of Eva, whose fossilisation must have taken place either at her place of death or after minimal transport, since the bones of her nearly complete skeleton are very well preserved. Most of the skeletal remains at Bellevue are unarticulated, and less than half of the bones are found in the best state of preservation. The preservation quality of the bones increases upward, which can be interpreted as result of a rapidly changing environment. The bones of the low fossil levels must have been deposited during a time of more violent water currents. The vertebrate remains at Bellevue show multiple types of fractures, some of which are of tectonic origin. The rest of the fractures are most likely the result of burial processes. The general bone orientation at Bellevue reflects the old current of the water, NW-SE. This suggests that the site underwent constant current influence during the Maastrichtian.

Chapter Two. The approach in the experimental section is a very simplified one. Nevertheless, it allowed me to make first attempts to answering the complex questions addressed. Further explorations in the section on climate suggest that shortly-spaced fluctuations in a tropical Aw-type climate setting were the main agent in depositing the sediments at Bellevue. Apart from this, lateral migration of the river was thought to be the second most important agent, because of the numerous fluctuations between channel and floodplain deposits in the Haute Vallée de l'Aude. Major storm events are a possibility, but are not perceived to have been the primary agent.

The dimensions of the ancient river or crevasse splay have been approached.

Although the models used in the experiment were faulty, I believe to have approached the minimum discharge value possible. The reconstruction of the paleoecology based

only on the fossil record for summer 2002 is fairly accurate, since the study was conducted using first principles, in this case biology.

Further Studies

As was stated before, the present study at the site of Bellevue is intended to be a comprehensive foundation for future studies, revisions and improvements. Topics for potential future studies are listed in the following paragraph.

A detailed mineralogical analysis of the Haute Vallée de l'Aude will improve the present insight into the provenance and history of the minerals. Once mineral occurrences are mapped, the sedimentological environment at the site of Bellevue can be studied in more detail. Detail will also be added by a microtectonic analysis. This could clarify the origin of bone fractures with a much higher resolution than presented here and solidify or modify any conclusions I have drawn about the taphonomy. In conjunction with this, another study could focus solely on bone orientations and cross-bedding structures at other outcrops in the region. A better idea about the direction and the dimensions of the ancient river could be obtained. Last, but not least, running different models for southern Europe in the Late Cretaceous will yield more solid conclusions than I have offered here.

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References

- ALBAGLI, S., and LURZ, T., 2002, Géologie et Taphonomie du Site de Bellevue (practicum report)
- ANDERSON, J.L., and STERN, W.F., 1999, Impact of large-scale circulation on tropical storm frequency, intensity, and location, simulated by an ensemble of GCM integrations: *Journal of Climate* 12(11): 3237-3254
- BADGLEY, C., 1986, Taphonomy of Mammalian Fossil Remains from Siwalik Rocks of Pakistan: *Paleobiology*, v. 12, p. 119-142
- BANNISTER, B.A., 1970, Ecological life cycle of *Euterpe globosa* Gaertn, Chapter B-18 in Odum, H.T. & Pigeon, R.F., (eds). *A tropical rain forest*, US Atomic Energy Commission, NTIS, Springfield, VA
- BARNES, R.F.W., 1983, Effects of elephant browsing on woodlands in a Tanzanian national park: Measurements, models and management: *Journal of Applied Ecology* 20: 521-540
- BEHRENSMEYER, A.K., 1978, Taphonomic and ecologic information from bone weathering: *Paleobiology*, v. 8, p.211-227
- BEHRENSMEYER, A.K., and DECHANT BOAZ, D.E., 1980, The recent bones of Amboseli Park, Kenya, in relation to East African paleoecology. In (A.K. Behrensmeyer & A. Hill, Eds) *Fossils in the Making*. Chicago: University of Chicago Press, pp. 77-92
- BEHRENSMEYER, A.K., 1987, Miocene fluvial facies and vertebrate taphonomy in Northern Pakistan: in ETHRIDGE, F.G., FLORES, R.M., and HARVEY, N.D., eds., *Recent Developments in Fluvial Sedimentology*: Society of Paleontologists and Mineralogists Special Publication, no. 39, p. 169-178
- BEHRENSMEYER, A.K., 1991, Terrestrial vertebrate accumulations. In (P.A. Allison & D.E.G. Briggs, Eds) *Taphonomy: Realising the Data Locked in the Fossil Record*. New York: Plenum Press, p. 291-335
- BENEDICT, F.G., 1870, *The physiology of the elephant*, Carnegie Institution of Washington
- BESSIÈRE, G., BILOTTE, M., CROCHET, B., PEYBERNES, B., TAMBAREAU, Y., and VILATTE, J., Erläuterungen zur Carte Géologique de la France, 1 : 50000, Nr. 1077 Quillan.-BRGM

- BICE, D., 2002, Geology Department, Carleton College, Personal Correspondence
- BILOTTE, M., 1984/1985, Le Crétacé Supérieur des Plates-Formes Est-Pyrénéennes, Laboratoire de Géologie Sédimentaire et Paléontologie, Université Paul-Sabatier, Toulouse, Atlas, Strata, Série 2, vol. 5; Série 1, vol. 1
- BOAZ, N.T., and BEHRENSMEYER, A.K., 1976, Hominid taphonomy: transport of human skeletal parts in an artificial fluvial environment: American Journal of Physical Anthropology, v. 45, p. 53-60
- BOGGS, S., Principles of Sedimentology and Stratigraphy, Macmillan Publishing Company, New York, 1987
- BRITANNICA, Macropedia, Knowledge in Depth, 16, Chicago-death, 1998, pp. 436-522
- BUFFETAUT, E., 1995, Dinosaurs de France, BRGM (Eds.), Pantin
- BURNS, J.J., MONTAGUE, J.J., COWLES, C.J., 1993, The Bowhead Whale, Special Publication Number 2, The Society for Marine Mammology
- BUSCH GARDENS Animal Information Database, 2002, webpage: www.seaworld.org
- CAMEL INFORMATION, webpage: www.arab-net.com
- CARRANO, M., 2001, Interview for National Geographic News “Eggs Hold Skulls of Titanosaur Embryos”
- COARD, R., 1997, One Bone, Two Bones, Wet Bones, Dry Bones: Transport Potentials Under Experimental Conditions: Journal of Archaeological Science, v. 26, p. 1369-1375
- CROCODILE INFORMATION, webpage: <http://teachit.acreekps.vic.au/animals/freshwatercrocodile.htm>
- CROWLEY, T.J., and NORTH, G.R., 1991, Paleoclimatology, Oxford University Press
- DAVIDSON, C., 2003, Personal Communication
- DAVIES, C., 2002, Data collection in southern Andalusia
- DINOPEDIA, 2002, webpage: http://www.jpoinstitute.com/dinopedia/dinocard/dc_ampel.html
- DINOSAUR DATABASE, 2002, webpage: <http://www.arts-letters.com/dino2/ency/DINORCDS05.html>

- DODSON, P., 1971, Sedimentology and taphonomy of the Oldman Formation (Campanian) Dinosaur National Park, Alberta, Canada: Paleogeography, Paleoclimatology, Paleoecology, v. 10, p. 21-74
- DUFFAUD, S., Personal Correspondence, 2002
- ENCHANTED LEARNING SOFTWARE, 1996-2001,
webpage: www.enchantedlearning.com/subjects/dinosaurs/facts/Ankylosaurus
- ESLINGER, E., 1988, Clay minerals for petroleum geologists and engineers, SEMP short course Nr. 22
- FREYTET, P., Toutin-Morin, N., Broutin, J., Debriette, P., Durand, M., El Wartiti, M., Gand, G., Kerp, H., Orszag, F., Paquette, Y., Ronchi, A. & Sarfati, J., 1999, Paleoecology of non-marine algae and stromatolites: Permian of France and adjacent countries. - Ann. Paléont., 85: 99-153.
- GAUTHIER-PITTERS, H., and DAGG, A.I., The Camel, 1981, The University of Chicago Press
- GERTSCH, L., 1994, Dinosaur tail dynamics: Wyoming Geological Association, Guidebook, Annual Field Conference, v. 44, p. 25-38
- GIELEWSKI, S., 1999, webpage: www.chelydra.org/weightcharts.html
- GROEBKE, I., 2001, Sedimentologie und Paläoökologie der oberen Kreide unter Kreide/Tertiärgrenze des Haute Vallée de l'Aude Südwestfrankreich (Diplomarbeit)
- HANSON, C.B., 1980, Fluvial taphonomic processes: models and experiments. In (A.K. Behrensmeyer & A. Hill, Eds) *Fossils in the Making*. Chicago: University of Chicago Press, p. 156-181
- HAILEAB, B., 2002, Geology Department, Carleton College, Personal Correspondence
- HEAD, J.J., 1998, A new species of basal hadrosaurid (Dinosauria, Ornithischia) from the Cenomanian in Texas: Journal of Vertebrate Paleontology 18: 718-738
www.palaeos.com/Vertebrates/Units/320Ornithischia/600.html
- HILL, A., and WALKER, A., 1972, Procedures in vertebrate taphonomy; notes on an Ugandan Miocene fossil locality: Journal of the Geological Society of London, v. 128, p. 399-406
- KEESEY, T.M., 2001, webpage: <http://dinosauricon.com/taxa/deinonychosauria.html>
- KERR, P.F., 1977, Optical Mineralogy, McGraw-Hill, Inc.

KHAJURIA, C.K., and PRASAD, G.V.R., 1998, Taphonomy of a Late Cretaceous mammal-bearing microvertebrate assemblage from the Decan inter-trappean beds of Naskal, peninsular India: *Paleogeography, Paleoclimatology, Paleoecology*, v. 137, p. 153-172

KYBURZ, R., 2002, webpage:
<http://www.pacsoa.org.au/palms/Astrocaryum/mexicanum.html>

LAURENT, Y., Personal Correspondence, 2002

LEEDER, M., 1999, *Sedimentology and Sedimentary Basins*, Blackwell Science

LE LOEUFF, J., 2002, Personal Correspondence

LE LOEUFF, J., and BUFFETAUT, E., 1998, webpage:
www.isgs.uiuc.edu/dinos/de_4/5caa488.htm

MARTIN, A.J., 2001, *Introduction to the Study of Dinosaurs*, Blackwell Science

MCKONE, M., 2002, Biology Department, Carleton College, Personal Correspondence

MCNOLDY, B.D., 1998-2002, Tropical Atlantic Activity Reports, webpage:
<http://www.mcwar.org/gallery/tropics/tropics.html>

MIALL, A.D., 1996, *The geology of fluvial deposits: sedimentary facies, basin analysis, and petroleum geology*, Berlin-New York: Springer Verlag

MICHELIN: Carte de France; 344 Local

NEW ZEALAND OSTRICH ASSOCIATION, 2002, webpage:
www.ostrich-association.co.nz/index.cfm/Facts

NICHOLLS, D., 1998, webpage:
<http://www.home.aone.net.au/byzantium/ferns/descriptions/blechnum/bcart.html>

OTTO-BLIESNER, B., BRADY, E.C., and SHIELDS, C., 2002, Late Cretaceous Ocean: Coupled Simulations with the NCAR CSM: *Journal of Geophysical Research-Atmospheres* 1:1-18

PALM & CYCAD SOCIETIES OF FLORIDA, Inc., 1998-2001, webpage:
http://www.plantapalm.com/vpe/photos/Species/phoenix_canariensis.htm

PALM & CYCAD SOCIETIES OF FLORIDA, Inc., 1998-2001, webpage:
http://www.plantapalm.com/vpe/photos/Species/chamaerops_humilis.htm

PALMER, M.A., 1992, Incorporating Lotic Meiofauna into our Understanding of Faunal Transport Processes: *Limnology and Oceanography*, v. 37, p. 329-341

PIÑERO, D., MARTINEZ-RAMOS, M. and SARUKHAN, J., 1984, A population model of *Astrocaryum mexicanum* and a sensitivity analysis of its finite rate of increase: *Journal of Ecology*, v. 72, pp. 977-991

PRIORE, C., 2002, Personal Correspondence

PROUDHON, B., 1993/1994, Fieldnotes of Bellevue

PROUDHON, B., and SCHULP, A., 1993-1996, Les gisements à dinosaures de la Haute Vallée de l'Aude (Campanien supérieur-Maastrichtien), Correlation à l'aide de l'analyse séquentielle et de la géomorphologie, Taphonomie du gisement de Bellevue (méthode, résultats et hypothèses)

PTERANODON WEBPAGE, webpage:

www.geocities.com/EnchantedForest/Cottage/5900/WhoIsWho/Pteranodon/html

RAND, M., 2002, Biology Department, Carleton College, Personal Correspondence

RITTER, D.F., KOCHER, R.C., MILLER, J.R., 1978, *Process Geomorphology*, Third Edition, McGraw-Hill

ROCKWOOD, L.L., 1973, The effects of defoliation on seed production of six Costa Rica tree species: *Ecology* 54: 1363-1369

RODGERS, B., and RODGERS, S., 2001, webpage:

www.reel-time.com/guidelines/default-new.asp

RUSSELL, R.A., Sedimentology of a lower Cretaceous fluvial system, Kootenai Formation, SW Montana, University of Arkansas, paper No. 149-0, 2001

SARUKHAN, J., 1978, Studies on the demography of tropical trees, pp. 163-184 in Tomlinson, P.B. & Zimmermann, H. (eds). *Tropical trees as living systems*, Cambridge University Press, Cambridge, England

SAUNDERS, M., and ROCKETT, P., 2001, Summary of the 2000/01 Australian Region Tropical Storm Season and Verification of Authors' Seasonal Forecasts, Benfield Greig Hazard Research Centre, UCL

SAVAGE, A.J., and ASHTON, P.S., 1983, The population structure of the double coconut and some other Secheylles palms: *Biotropica* 15: 15-25

SAVINA, M., 2002, Geology Department, Carleton College, Personal Correspondence

SCHULP, A., 1996, Taphonomy of Maastrichtian Dinosaurs from the Bellevue site, Campagne-sur-Aude (dep. Aude, France), Report on the data collected during the 1994 and 1995 excavations by the Association DINOSAURIA

SHARPE, J.M., 1993, Plant Growth and Demography of the Neotropical Herbaceous Fern *Danaea wendlandii* (Marattiaceae) in a Costa Rican Rain Forest: *Biotropica* 25: 85-94

SHIPMAN, P., 1981, *Life History of a Fossil*, Cambridge, MA; Harvard University Press

SINGER, S., 2002, Biology Department, Carleton College, Personal Correspondence

SKEAN, D., 1990, webpage:
<http://www.albion.edu/plants/presmopg.htm>

SMITH, R.M.H., 1993, Vertebrate Taphonomy of Late Permian Floodplain Deposits in the Southwestern Karoo Basin of South-Africa: *Palaios*, v. 8, p. 45-67

TODD, L.C., and RAPSON, D.J., 1987, Long Bone Fragmentation and Interpretation of Faunal Assemblages: Approaches to Comparative Analysis: *Journal of Archaeological Science*, v. 15, p. 307-325

TRIVEDI, B.P., 2001, Interview for National Geographic News "Eggs Hold Skulls of Titanosaur Embryos"

WALKER, R.G., and JAMES, N.P. 2001, *Facies Models*, Geological Association of Canada

WATERHOUSE, F.L.S., and QUINN, C.J., 1978, Growth patterns in the stem of the palm *Archontophoenix cunninghamiana*: *Botanical Journal of the Linnean Society* 77: 73-93

WOLF WEB, 1999-2001, webpage: <http://www.wolfweb.com/facts-pack.html>

WOOD, J.M., THOMAS, R.G., and VISSER, J., 1988, Fluvial processes and vertebrate taphonomy: The Upper Cretaceous Judith River Formation, south-central Dinosaur Provincial Park, Alberta, Canada: *Paleogeography, Paleoclimatology, Paleoecology*, v. 66, p. 127-143

ZANN, R.A., 1996, *The Zebra Finch*, Oxford University Press

Appendix

Appendix 1

The following two lists are the basis for the taphonomic section of this study.
This is a list (in French) of the bone material that Anne Schulp used for her bone analysis.

Nr.	Date	Détermination	Nature	Dtr.	Pend.	Pres.	Strat.	Lon.	Lar
1	01-01-1983	Titanosauridae	humérus						
1	01-01-1983	Titanosauridae	humérus						
2	01-01-1983		vert. caudale postérieure						
3	01-01-1983		vert. caudale postérieure						
4	01-01-1983		vert. caudale postérieure						
5	01-01-1983		vert. caudale postérieure						
6	01-01-1983		vert. caudale postérieure						
7	01-01-1983		vert. caudale postérieure						
8	01-01-1989		vert. caudale						
9	01-01-1989		frag. côte						
10	01-01-1989		frag. côte						
11	01-01-1989		esquille os long						
12	01-01-1989		frag.						
13	01-01-1989		esquille os						
14			frag.						
15			frag.						
16			frag.						
17			frag.						
18			frag.						
19			frag						
20	01-01-1989	Titanosauridae	fémur						
21	01-01-1989	Titanosauridae	scapula						
22	01-01-1989	Titanosauridae	coracoïde						
23	01-01-1989	Titanosauridae	plaque sternale						
24	01-01-1989	Titanosauridae	vertèbre caudale						
25	01-01-1989	Titanosauridae	vertèbre caudale						
26	01-01-1989	Titanosauridae	vertèbre caudale						
27	01-01-1989	Titanosauridae	vertèbre caudale (centrum)						
28		Rhabdodon	vertèbre caudale						
29	01-01-1990								
30		Titanosauridae	vertèbre caudale						
31		Titanosauridae	vertèbre caudale						
32		Titanosauridae	côte						

238									
239									
240									
241	01-01-1994		os long						
242	01-01-1994	Titanosauridae	vertèbre caudale						
243	01-01-1994		plaque dermique?						
244									
245									
246									
247	01-01-1994	Titanosauridae	vertèbre dorsale				f2b		
248									
249	01-01-1994	Rhabdodon	vertèbre caudale				f2		
250	01-01-1994		plaque dermique						
251	01-01-1993	Lepisosteidae	ecouille						
252	01-01-1993	Lepisosteidae	ecouille						
253	01-01-1993	Lepisosteidae	dent indet						
254								32,0	19,0
255	01-01-1994						f2		
256	01-01-1994		vertèbre						
257	01-01-1994	Rhabdodon	vertèbre caudale				f2		
258	01-01-1994	Titanosauridae	vertèbre dorsale						
259	01-01-1994		os long				f4		
260									
261	01-01-1994	Titanosauridae	fémur				f5		
262									
263	01-01-1994		humérus				f3		
264	01-01-1994		vertèbre						
265	01-01-1994	Titanosauridae	vertèbre cervicale				f5		
266	01-01-1994	Vegetal					f2b		
267	01-01-1994	Omithopode	fémur						
268	01-01-1994		os indet						
269									
270	01-01-1994		petit os				f3		
271									
272	01-01-1994		métapode				f3		
273	01-01-1994		vertèbre caudale postérieure	120	18		f2	13,0	9,0
274			os indet						
275	01-01-1994		os creux	190			f2b	16,0	4,0
276	01-01-1994	Crocodile	arrière crâne				f4		
277	01-01-1994	Crocodile	humérus	125	0		f3	10,0	
278	01-01-1994	Titanosauridae	vertèbre caudale (centrum)				f1b	12,0	12,0

279	01-01-1994	Crocodile	vertèbre	110			f1b	8,0	6,0
280	01-01-1994		os indet						
281	01-01-1994	Crocodile	dent	135			f1b	4,0	2,0
282									
283	01-01-1994		os indet				f1b		
284	01-01-1994	Titanosauridae	os indet						
285	01-01-1994		os bassin	40	0		f5	38,0	15,0
286	01-01-1994	Titanosaurodae	vertèbre caudale	40	0		f4	18,0	11,0
287				0	5		f3	90,0	30,0
288	01-01-1994	Omithopode?	métapode	70	5		f3	17,0	5,5
289	01-01-1994	Titanosauridae	phalange	20	30		f3	15,0	8,0
290				290	10		f3	20,0	11,0
291	01-01-1994		côte	132	0		f5	68,0	7,0
292	01-01-1994	Omithopode?	sacrum	86	0		f1b	11,0	3,0
293	01-01-1994	Titanosauridae	vertèbre dorsale				f1b	15,0	15,0
294	01-01-1994	Titanosauridae	plaque dermique?	288	10		f2b	130,0	7,5
295				258	15		f2b	111,0	5,0
296	01-01-1994		os indet				f1b		
297	01-01-1994		vertèbre	100			f3	6,0	4,0
298	01-01-1994		plaque	80			f3	6,0	4,0
299	01-01-1994		os indet	68	20		f5	8,5	4,5
300	01-01-1994		tibia	10	20		f4	48,0	23,0
301	01-01-1994		os long	290	0		f5	35,0	12,0
302	01-01-1994		fémur	60	8		f2b	33,0	9,0
303			indet	190	20		f2b	12,0	10,0
304				0	25		f2	19,0	6,0
305	01-01-1994	Omithopode	tibia	336	0		f5	16,0	4,0
306	01-01-1994		os long	180	40		f2	20,0	4,0
307	01-01-1994	Titanosauridae	metacarpien	180	0		f1b	30,0	15,0
308	01-01-1994	Tortue	carapace	244	0		f2	6,0	5,0
309	01-01-1994		vertèbre	114	0		f2	13,0	9,0
310		Omithopode	tibia	50	0		f3	47,0	15,0
311	01-01-1994		frag.						
312	01-01-1994	Titanosauridae	humérus	20	0		f3	68,0	32,0
313	01-01-1994		os indet	20	15		f3	25,0	16,0
314	01-01-1994	Titanosauridae	vertèbre dorsale + centrum	40	0		f3	22,0	12,0
315	01-01-1994		os plat	138	0		f5	12,0	5,0
316	01-01-1994		indet	155	12		f1b	27,0	12,0
317				330			f5	63,0	8,0
318		Omithopode							
319				179	0		f1b	25,5	3,0

320			indet	268	12		f2b	10,0	8,0
321	01-01-1994	Ankylosauridae	scapula	240	0		f5	34,0	16,0
322	01-01-1994	Tortue	plaque	250	0		f4	7,5	2,5
323				290	10		f2b	66,0	8,0
324				142	0		f2b		
325	01-01-1994		plaque dermique	110	0		f2b	26,0	15,0
326	01-01-1994	Crocodylien	ilion	124	0		f2b	9,0	6,5
327				328	10		f3	24,0	8,0
328				272	0		f3	35,0	14,0
329	01-01-1994		indet	8	0		f3	18,0	5,0
330	01-01-1994		indet	220	10		f4	34,0	12,0
331				310	4		f4	44,0	7,0
332									
333	01-01-1994		indet	70	0		f2b	9,0	3,0
334	01-01-1994	Titanosauridae	vertèbre caudale	50	8		f2b	13,0	12,0
335	01-01-1994	Titanosauridae	vertèbre caudale	172	0		f3	25,0	15,0
336	01-01-1994		indet	162	18		f3	25,0	18,0
337	01-01-1994	Ornithischien	vertèbre caudale anterieure	300	0		f2b	14,0	12,0
338	01-01-1994	Rhabdodon	fémur	314	12		f2b	57,0	17,0
339	01-01-1994	Crocodile	vertèbres sacrées	50	12		f2b	13,0	10,0
340	01-01-1994	Titanosauridae		243	2		f2b	18,0	11,0
341	01-01-1994	Titanosauridae	os indet	298	14		f2b	21,0	20,0
342	01-01-1994		os indet	280	10		f2b	13,0	8,0
343	01-01-1994	Rhabdodon	vertèbre	78	12		f2b	6,5	4,0
344	01-01-1994	Rhabdodon	vertèbre dorsale	82	12		f2b	15,0	9,0
345	01-01-1994	Titanosauridae	vertèbre caudale	148	0		f5	17,0	1,0
346	01-01-1994	Titanosauridae	côte	224	0	4	f3	58,0	5,5
347	30-08-1994	Titanosauridae	vertèbre dorsale				f3	14,5	17,0
348	30-08-1994			322	9	5	f2b	37,0	17,0
349	01-01-1994	Rhabdodon	fémur	60	0		f4	38,0	10,5
350	01-01-1994	Titanosauridae	vertèbre caudale	20	0		f2	20,0	10,0
351	01-01-1994	Titanosauridae	coracoïde				f2b		
352	01-01-1994	Theropoda	indet.dent						
353	01-01-1994	Theropoda	indet.dent						
354	01-01-1994	Theropoda	indet.dent						
355	01-01-1994	Crocodile	dent						
356	01-01-1994	Crocodile	dent						
357	01-01-1994	Crocodile	dent						
358	01-01-1994	Crocodile	dent						
359	01-01-1994	Crocodile	dent						
360	01-01-1994	Crocodile	dent						

484									
485									
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500	03-07-1995	Titanosauridae	radius	150	5	4		28,0	7,0
501	03-07-1995	Titanosauridae	indet	290	6			31,0	7,0
502	04-07-1995	tortue	plaque						
503	04-07-1995	croco	dent						
504	05-07-1995	Rhabdodon	vertèbre caudale	270	18	3		8,5	6,5
505	05-07-1995	Titanosauridae	côte	92	8	4	13	28,0	1,5
506	06-07-1995		os indet.			4		5,0	3,5
507	06-07-1995	Rhabdodon	vertèbre caudale	90	10	4		12,0	9,0
508	06-07-1995	Rhabdodon?	crâne	149	19	3		9,0	8,0
509	06-07-1995	Crocodile	dent						
510	08-07-1995	Rhabdodon	métacarpien	120	8	5	14	8,0	5,0
511	08-07-1995	Titanosauridae	tibia	310	4	2	14	45,0	11,0
512	11-07-1995		metacarpien	262	8	4	13	14,0	7,0
513	11-07-1995						13		
514	11-07-1995			110	0	4	12b	39,0	8,0
515	11-07-1995		os indet	120	0	4	13	10,5	7,0
516	11-07-1995		fémur?	320	10	2	13	28,0	10,0
517	11-07-1995		vertebra	120	6	1	13	13,0	6,0
518	12-07-1995	Titanosauridae	côte	65	0	4	13	54,0	4,0
519	12-07-1995			170	20	5	13	15,0	6,0
520	12-07-1995			110	20	2	13?	18,0	6,0
521	12-07-1995		machoire indet	278	50	3	14?	12,5	5,0
522	12-07-1995	Titanosauridae	vertèbre caudale	342	18	4		12,0	10,0
523	12-07-1995	Titanosauridae	vertèbre caudale	234	22	2		11,0	5,0
524	13-07-1995	Rhabdodon	fémur	40	8	2	13	28,5	10,0

525	13-07-1995	Aves	sacrum	90	0	5	f2b	18,2	4,0
526	13-07-1995	Titanosauridae	scapula	58	0	3	t2	58,0	24,0
527	16-07-1995	Titanosauridae	fémur	280	8	2	f2b	64,0	18,0
528	16-07-1995			138	22	3	f2b	15,0	6,0
529	16-07-1995	omithopod	radius	66	6	3	f2b	41,0	13,0
530	18-07-1995		indet	308	14	2	t2	42,0	21,0
531	18-07-1995	Titanosauridae	plaque dermique	50	0	1	t3	13,0	13,0
532	18-07-1995		esquille	210	15	3	t2	11,0	10,0
533	18-07-1995			34	24	2	t2	35,0	17,0
534	18-07-1995			154	0	4	f2b	22,0	12,0
535	19-07-1995	Ornithopode	vertèbre caudale	95	0	3	t3	10,0	5,0
536	19-07-1995		indet.	90	0	3	t3	5,0	3,5
537	19-07-1995		indet	180	52	3	t3	6,0	3,0
538	20-07-1995		esquille	46	13	1	t3	17,0	6,0
539	20-07-1995			65	0	3	f2b	17,0	4,0
540	20-07-1995			270	4	4	f2b	27,0	10,0
541	20-07-1995			344	3	1	t2	20,0	3,0
542	20-07-1995			262	2	4	t2	54,0	6,5
543	20-07-1995			324	16	3	t3	30,0	8,0
544	20-07-1995	Titanosauridae	fémur	30	0	4	t3	50,0	24,0
545	20-07-1995	Titanosauridae	vertèbre caudale	0	90	3		9,0	9,0
546	20-07-1995	theropode?	fémur	320	5	5	t5	18,0	5,0
547	20-07-1995		falange	20	0	2		6,0	5,0
548	21-07-1995	Titanosauridae	indet	198	28	3	t3	18,0	5,0
549	21-07-1995	Titanosauridae	côte	53	0	3	t2	81,0	12,0
550	21-07-1995	Titanosauridae	cole	10	10	1	f2b	52,0	5,0
551	22-07-1995					5	t3?		
552	22-07-1995	Titanosauridae	radius	278	12	4	f2b	18,0	9,0
553	22-07-1995	Titanosauridae	vertèbre caudale			2	f2b	11,0	6,0
554	22-07-1995		indet	274	9	3	t2	34,0	6,0
555	22-07-1995		indet	120	32	2	t2	14,0	9,0
556	22-07-1995			250	35	4	t2	26,0	9,0
557	22-07-1995		chevron	238	16	2	t2	28,0	4,0
558	22-07-1995		indet	10	20	3	t2	13,0	7,0
559	22-07-1995	Titanosauridae	plaque dermique	90	2		f2b	5,0	3,0
560	22-07-1995	Titanosauridae	tibia	44	0	4	f2b	47,0	15,0
561	22-07-1995		indet	100	0	3	f2b	9,0	3,5
562	22-07-1995	Titanosauridae	fémur	78	0	4	f2b	71,0	27,0
563	22-07-1995	Titanosauridae	tibia	311	10	3	f2b	39,0	13,0
564	22-07-1995		indet	90	0	2	t2	15,0	7,0
565	22-07-1995		indet	68	12	2	t2	17,0	6,0

566	22-07-1995	Titanosauridae	côte	54	0	1	t3	46,0	6,0
567	24-07-1995	Titanosauridae	fémur	338	23	2	t2b	80,0	24,0
568	22-07-1995	Titanosauridae	côte	20	0	3	t3	62,0	8,0
569	22-07-1995	Titanosauridae	vertèbre	62	0	2	t3	13,0	10,0
570	22-07-1995	Titanosauridae	côte	290	22	2	t3	35,0	7,0
571	22-07-1995	Titanosauridae	côte	38	0	2	t3	17,0	4,0
572	22-07-1995	Titanosauridae	côte	330	17	1	t3	40,0	4,0
573	22-07-1995	Titanosauridae	métapode	300	8	2	t3	19,0	6,0
574	22-07-1995			76	18	3	t2b	45,0	14,0
575	22-07-1995			118	0	1	t2		
576	22-07-1995	Ptérosaure	metacarpien	50	16	2	t3	26,0	3,0
577	22-07-1995	Ptérosaure	metacarpien	348	12	2	t3	18,0	3,0
578	22-07-1995	Crocodile	dent			5	t2	1,3	0,5
579	24-07-1995	Titanosauridae	humerus	165	18	3	t2	71,0	24,0
580	24-07-1995		indet	78	0	2	t2	12,0	4,0
581	24-07-1995			86	0	1	t2	39,0	36,0
582	24-07-1995	Titanosauridae	fémur	280	14	1	t2b	53,0	22,0
583	24-07-1995	Titanosauridae	vertèbre caudale			1	t2	16,0	10,0
584	24-07-1995	Rhabdodon	fémur	328	6	3	t2b	51,0	14,0
585	26-07-1995	Titanosauridae	falange?				t2b		
586	26-07-1995		indet	0	0	1	t2	17,0	9,0
587	28-07-1995			270	8	2	t2	13,0	7,0
588	28-07-1995	Titanosauridae	vertèbre caudale	79	2	2	t2b	7,0	3,0
589	26-07-1995	Titanosauridae	chevron	64	0	3	t2	11,0	3,5
590	26-07-1995	Titanosauridae	vertèbre	90	0	3	t2	14,0	5,0
591	28-07-1995		indet	0	24	2	t3	47,0	6,0
592	28-07-1995	Titanosauridae	scapula	356	21	3	t2b	52,0	30,0
593	28-07-1995	Titanosauridae	ischion	30	18	4	t2b	47,0	24,0
594	28-07-1995	Titanosauridae	ischion	60	0	2	t2b	38,0	10,0
595	28-07-1995			50	0	1	t2b	15,0	11,0
596	28-07-1995			28	0	2	t2b	32,0	6,0
597	28-07-1995	Omithopode	Métapode	0	0	4	t3	7,0	3,5
598	28-07-1995			18	0	1	t2b	42,0	6,0
599	29-07-1995		indet	78	0	3	t2b	8,0	6,0
600	29-07-1995		indet	64	18	4	t2	24,0	7,0
601	29-07-1995	Rhabdodon	vertèbre caudale	28	0	3	t2b	5,0	4,0
602	31-07-1995	Titanosauridae	humérus	290	20	2	t2b	39,0	16,0
603	01-08-1995		tête d'un os	30	0	3	t3	7,0	6,0
604	01-08-1995		indet	98	0	4	t2	5,0	1,0
605	01-08-1995	Titanosauridae	ulna	326	18	3	t2b	40,0	27,0
606	01-08-1995	Titanosauridae	vertèbre dorsale	70	0	2	t2b	20,0	7,0

607	01-08-1995	Titanosauridae	côte	31	0	3	t2	120,0	8,0
608	02-08-1995		esquille os long indet	250	16	3	t2b	11,0	5,0
609	02-08-1995		astragale	152	0	3	t2	10,0	9,0
610	02-08-1995	Titanosauridae	plaque dermique	50	0	4	t2	8,0	4,0
611	02-08-1995	Rhabdodon	vertèbre caudale		0	4	t2b	9,0	7,0
612	02-08-1995	Titanosauridae	vert. caud. prezygapophyse	132	8	2	t2b	9,0	4,0
613	02-08-1995	Crocodile	dent	98	0	5	t2	2,0	0,5
614	02-08-1995	Tortue	plaque	358	18	5	t2b	7,0	7,0
615	02-08-1995	Titanosauridae	bout de vert. caudale	124	0	1	t2b	11,0	6,0
616	02-08-1995	Rhabdodon	vertèbre	20	0	4	t2	6,0	6,0
617	02-08-1995	Titanosauridae	vertèbre caudale	228	0		t2	13,0	10,0
618	02-08-1995	Titanosauridae	vertèbre dorsale frag.	120	22	3	t2b	10,0	5,0
619	02-08-1995	Titanosauridae	plaque dermique	168	0		t2	6,0	5,5
620	02-08-1995	Rhabdodon	vertèbre		0		t2	8,0	6,0
621	02-08-1995	Rhabdodon	arc neurale	100	0		t2	8,0	9,0
622	02-08-1995	Rhabdodon	vertèbre caudale	100	0	2	t2b	7,0	6,0
623	02-08-1995			110	30		t2b		
624	02-08-1995	Titanosauridae	vert. caud. moyenne	172	2	3	t2b	22,0	12,0
625	02-08-1995	Tortue	carapace	252	9	3	t3	7,0	4,0
626	02-08-1995		indet				t2		
627	03-08-1995			160	44	4	t2	6,0	4,5
628	03-08-1995	Tortue	plaque			5	t2		
629	03-08-1995		esquille	34	0	3	t3	9,0	5,0
630	03-08-1995	Rhabdodon	os indet.		0	4	t2	7,0	5,0
631	03-08-1995	Titanosauridae	côte	20	0	3	t2	19,0	5,0
632	03-08-1995		indet		0	3	t2	6,0	5,0
633	03-08-1995	Titanosauridae	fibula	100	0		t2b		
634	04-08-1995		indet	230	14	3	t2b	9,0	6,0
635	04-08-1995			326	18	3	t3	9,0	7,0
636	04-08-1995		indet	70	12	3	t2b	29,0	7,0
637	04-08-1995			352	0	2	t2b	59,0	25,0
638	04-08-1995	Titanosauridae	femur	90	10	3	t2	63,0	16,0
639	04-08-1995		indet	286	14	4	t2	6,0	1,0
640	04-08-1995	Titanosauridae	esquille (?) vert dors.	170	0	1	t2b	10,0	7,0
641	04-08-1995			98	0	3	t2b	14,0	2,0
642	04-08-1995					4	t2b	4,0	3,0
643	04-08-1995			58	0	3		5,0	4,0
644	07-08-1995	Theropoda	dent	308	0		t3	1,0	0,5
645	07-06-1995		indet	130	0	3	t2b	10,0	9,0
646	07-08-1995		indet	118	12	2	t3	20,0	3,0
647	07-08-1995		indet		94	0	t3	5,0	3,0

648	07-08-1995			12	17	1	f2b	65,0	28,0
649	07-08-1995			124	0	3	f2b	62,0	5,0
650	07-08-1995			114	8	2	f2b	28,0	12,0
651	07-08-1995		vert?	98	0	1	f2b	51,0	20,0
652	07-08-1995			160	12	3	f2b	16,0	9,0
653	07-08-1995	Tortue	plaque	176	30	3	f2b	5,0	4,0
654	07-08-1995	Titanosauridae	vert. caudale post.	172	0	3	f2b	13,0	7,0
655	08-08-1995	Titanosauridae	vertèbre caudale	40	0	4	f2	8,0	7,0
656	08-08-1995	Titanosauridae	arc neurale dorsale	240	17	3	f2	10,0	9,0
657	08-08-1995			51	2	3	f2	9,0	2,0
658	08-08-1995	Titanosauridae	côte	84	14	3	f3	40,0	3,0
659	08-08-1995		os à dents	78	6	4	f2	10,0	2,0
660	08-08-1995		esq. os long. indet.	72	0	2	f2b	17,0	3,0
661	08-08-1995		esq. os long. indet.	102	3	3	f2b	16,0	2,0
662	08-08-1995		vertèbre		90	4	f2	2,0	2,0
663	09-08-1995	Crocodile	dent			5	f2b		
664	09-08-1995			168	0	3	f2	10,0	4,0
665	09-08-1995	Tortue	plastron	308	28	4	f3	14,0	5,0
666	10-08-1995	Titanosauridae	chevron	50	0	3	f2	22,0	9,0
667	10-08-1995			90	7	3	f2b	22,0	10,0
668	10-08-1995	Titanosauridae	indet			1	f3	7,0	6,0
669	10-08-1995	Crocodile	dent			4	f2b		
670	10-08-1995		esquille	10	0	1	f2	11,0	9,0
671	10-08-1995	Titanosauridae	vertèbre roulée	36	0	1	f2	14,0	10,0
672	10-08-1995		os long indet - esquille	36	16	2	f2b	22,0	2,0
673	10-08-1995		indet	290	28		f2b	8,0	3,0
674	10-08-1995		indet	228	24	3	f2b	9,0	6,0
675	10-08-1995	Titanosauridae	plaque			1	f2		
676	10-08-1995		esquille	124	0		f2b	9,0	4,0
677	10-08-1995		indet	288	24	1	f2b	7,0	4,0
678	10-08-1995	Titanosauridae	vert. caud. plutôt pst.			2	f2	12,0	11,0
679	10-08-1995	Tortue	plaque	212	10	1	f2	6,0	5,0
680	11-08-1995			29	0	3	f2b	51,0	15,0
681	11-08-1995	Crocodile	dent	296	22	5	f2	1,0	0,5
682	11-08-1995		indet	64	0	2	f2b	15,0	7,0
683	11-08-1995		tête os long indet.	56	12	2	f2	12,0	6,0
684	11-08-1995	Titanosauridae	phalange	126	42	4	f2b	5,0	4,0
685	12-08-1995		boule osseuse roulée	208	6	1	f2	24,0	12,0
686	11-08-1995		esquille	73	0	3	f2	12,0	4,0
687	11-08-1995			54	0	3	f2b	9,0	3,0
688	14-08-1995	Titanosauridae	ilium	240	8	4	f2b	46,0	33,0

689	14-08-1995	Tortue	carapace?	94	56	5	t2b	8,0	7,0
690	14-08-1995		tête d'os long	2	38	3	t2b	24,0	17,0
691	14-08-1995		os long indet	118	0	2	t2b	14,0	3,0
692	14-08-1995	Titanosauridae	esquille vert. dors.	60	0	1	t2b	11,0	9,0
693	14-08-1995			156	4	4	t2b	22,0	11,0
694	14-08-1995		côte	66	0	3	t2b	40,0	2,0
695	14-08-1995			46	0	2	t2	22,0	4,0
696	14-08-1995			166	0	2	t2b	15,0	6,0
697	15-08-1995			88	0	2	t2b	7,0	4,0
698	15-08-1995	Titanosauridae	vertèbre caudale	45	0	4	t2b	16,0	11,0
699	15-08-1995	Crocodile	dent	102	0	5	t2	1,5	0,5
700	15-08-1995	Rhabdodon	scapula	109	0	4	t2b	32,0	12,0
701	16-08-1995	Titanosauridae	côte	72	0	3	t2	25,0	3,0
702	16-08-1995		indet	326	22	3	t2b	33,0	10,0
703	16-08-1995		os long indet	326	22	3	t2b	20,0	3,0
704	16-08-1995		os long indet	10	28	3	t2b	15,0	5,0
705	16-08-1995	Titanosauridae	vertèbre dorsale	90	0	1	t2b	12,0	8,0
706	18-08-1995	Titanosauridae	vertèbre dorsale			3	t2b		
707	18-08-1995	Titanosauridae	dorsal vertebra			3	t2b		
708	18-08-1995			138	0	3	t2b	42,0	21,0
709	18-08-1995			310	18	3	t2b	18,0	5,0
710	18-08-1995	Titanosauridae	côte	44	18	3	t2b	137,0	7,0
711	18-08-1995			45	0	3	t3	10,0	6,0
712	18-08-1995	Pterosaure?	os long	22	18	3	t2b	11,0	2,5
713	18-08-1995	Rhabdodon	scapula	68	16	4	t3	30,0	12,0
714	18-08-1995			158	8	3	t2	27,0	9,0
715	18-08-1995	Crocodile	machoire + 2 dents	80	0	3	t2b	5,0	2,0
716	18-08-1995	Theropoda	dent	60	0	4	t2	1,0	0,5
717	18-08-1995	Tortue	plaque	56	0	4	t2b	8,0	5,0
718	18-08-1995	Rhabdodon	humerus	102	0	3	t3	31,0	11,0
719	18-08-1995		indet	76	8	2	t3	11,0	3,0
720	18-08-1995					3	t3	9,0	5,0
721	19-08-1995	Titanosauridae	radius	312	9	3	t3	39,0	10,0
722	19-08-1995	Rhabdodon	ischion	46	0	4	t3	34,0	15,0
723	19-08-1995	Pterosaure	metacarpien	74	7	3	t3	28,0	1,0
724	19-08-1995			242	6	2	t3	20,0	10,0
725	19-08-1995	Crocodile	dent	56		3	t2	2,0	0,7
726	19-08-1995	Tortue	plaque	100		3	t2	5,0	5,0
727	21-08-1995					3	t3	8,0	3,0
728	21-08-1995	Titanosauridae	côte	62	0	3	t2	55,0	5,5
729	21-08-1995			63	0		t2	7,0	4,0

730	21-08-1995	Tortue	plaque	82	0	3	t2	7,0	5,0
731	21-08-1995	Tortue	plaque	166	0	4	t2	4,0	3,5
732	21-08-1995		indet	54	9	4	t3	24,0	3,0
733	21-08-1995	Crocodile	vertèbre			4	t3	4,0	3,0
734	22-08-1995	Tortue	2 plaques/carapace	96	16	4	t3	12,0	8,0
735	22-08-1995	Omithopode	coracoïde	88	21	4	t3	9,0	8,0
736	23-08-1995		indet tête de côte	170	0	4	t3	15,0	5,0
737	23-08-1995		indet	124	0	4	t3	16,0	2,0
738	24-08-1995			246	42	1	t2b	7,0	4,0
739	24-08-1995	Rhabdodon	fémur	52	0	4	t3	35,0	9,0
740	24-08-1995			354	23	1	t2b	35,0	8,0
741	24-08-1995			100	0	3	t3	9,0	7,0
742	24-08-1995			77	42	3	t2b	14,0	7,0
743	24-08-1995		indet	42	0	4	t3	7,0	3,0
744				46	0	3	t3	5,0	2,0
745				336	10	2	t3	13,0	13,0
746		Crocodile	dent	120	0	4	t3	1,1	0,5
747		Tortue	plaque	108	0	3	t2b	10,0	4,0
748			dent	50	26	4	t2b	1,0	0,6
749	25-08-1995	Crocodile	dent	72	0	1	t2	1,6	1,3
750	25-08-1995	Titanosauridae	côte	6	0	3	t2b	32,0	7,0
751	25-08-1995	Titanosauridae	côte	294	40	2	t2b	30,0	5,0
752	25-08-1995	Crocodile	dent			2	t2b	1,5	0,5
753	25-08-1995		os long indet	64	0	3	t3	9,0	6,0
754	25-08-1995		indet	173	0	3	t3	5,0	1,5
755		Titanosauridae	vertèbre caudale	104	0	2	t3	10,0	10,0
756			côte	321	22	2	t2b	36,0	4,0
757		Tortue				4	t3	8,0	5,0
758				324	42	1	t2b	10,0	4,0
759	26-08-1995	Rhabdodon	fibula	78	22	4	t4	36,0	8,0
760	26-09-1995	Titanosauridae	posterior caudal vertebra	124	8	4	t3	8,0	5,0
761	28-08-1995	Titanosauridae	crâne	40	22	3	t3	16,0	12,0
762	28-08-1995	Crocodile	dent			4	t2b	0,5	0,4
763	29-08-1995	Titanosauridae	dent	30	0	3	t2b	1,5	0,5
764	29-08-1995	Titanosauridae	vertèbre dorsale	342	10	2	t2b	27,0	18,0
765		Tortue	plaque dermique						
766	01-01-1995	Crocodile	dent				t3		
767		Tortue	plaque dermique						
768	01-01-1995	Tortue	plaque dermique				t3		
769	01-01-1995		tête d'os long						
770	01-01-1995	Crocodile	ilium						

771	01-01-1995	Crocodile	dent						
772	01-01-1995		indet						
773	01-01-1995	Titanosauridae	vertèbre						
774	01-01-1995	Tortue	crane				f3		
775	16-01-1996	Rhabdodon	vertèbre dorsale				f3		
776		Lepisosteidae	ecouille				f2b		
777		Lepisosteidae	empreinte ecouille						
778		Lepisosteidae	ecouille						
779		Lepisosteidae	ecouille						
780	01-01-1995	Crocodile	dent				f4		
781	01-01-1995	Crocodile	dent				f2b		
782	01-01-1995	Crocodile	dent						
783	01-01-1995	Crocodile	dent						
784	01-01-1995	Crocodile	dent						
785	01-01-1995		dent						
786	01-01-1995		indet						
787	01-01-1995		vertèbre						
788	01-01-1995	Theropoda	dent						
789	01-01-1995	Tortue	plaque dermique						
790	01-01-1995		dent						
791	01-01-1995		dent						
792	01-01-1995		dent						
793	01-01-1995		dent						
794	01-01-1993	Crocodile - trematochampsidae	dent						
795		Crocodile	dent						
796		Crocodile	dent						
797		Crocodile	dent						
798		Crocodile	dent						
799		Crocodile	dent						
800		Crocodile	dent						
801		Crocodile	dent						
802	01-01-1993	Crocodile	vertèbre sacrée						
803	01-01-1992	Crocodile	arrière crâne						
804		Crocodile	dent						
805		Crocodile	dent						
806		Crocodile	dent						
807	01-01-1993	Tortue	humérus						
808		Crocodile	dent						
809		Rhabdodon	dent						
810		Lepisosteidae	ecouille						

This is a list of the bone remains present during my fieldwork at the site of the summer of 2002.

Animal	Nature	Length (cm)	Width (cm)	Orientation (°)
Titanosaur (Eva begins here)	femur	96	21	356
titanosaur	rib	-	-	120
titanosaur	rib	-	-	110
titanosaur	cervical vertebrae	-	-	140
titanosaur	vertebrae	-	-	130
titanosaur	cervical vertebrae	-	-	178
titanosaur	cervical vertebrae	7.3	1.6	270
titanosaur	cervical vertebrae	13.6	3.3	299
titanosaur	cervical vertebrae	14.3	3.7	292
titanosaur	rib	14.8	8.1	274
titanosaur	rib fragment	8.8	1.0	212
titanosaur	shoulder part	5.4	8.1	200
titanosaur	shoulder part	8.6	14.7	280
titanosaur	shoulder part	18.7	5.3	280
titanosaur	rib	10.3	3.4	296
titanosaur	rib	21.9	2.0	284
titanosaur	rib	18.2	4.1	284
titanosaur	rib	11.1	6.7	302
titanosaur	shoulder part	9.0	7.0	280
titanosaur	rib	12.3	3.2	280
titanosaur	rib	19.9	2.0	291
titanosaur	scapula part	11.4	4.1	331
titanosaur	metapod	18.7	4.9	292
titanosaur	metapod	19.0	11.8	268
titanosaur	metapod	7.1	1.1	210
titanosaur	sternal plate	26.8	10.3	314
titanosaur	rib	15.3	2.7	322
titanosaur	shoulder	20.6	15.2	10
titanosaur	rib	11.9	5.2	252
titanosaur	rib	45.0	16.7	274
titanosaur	scapula	5.0	1.0	252
titanosaur	rib fragment	12.2	11.2	338
titanosaur	rib fragment	13.6	4.6	42
titanosaur	rib	26.3	3.4	332

titanosaur	rib fragment	9.1	1.0	18
titanosaur	rib	16	5.1	0
titanosaur	rib fragment	21.3	15.1	330
titanosaur	rib fragment	15.0	15.0	290
titanosaur	rib fragment	33.0	2.3	240
titanosaur	dorsal vertebrates	62.0	11.6	259
titanosaur	rib fragment	38.5	13.3	272
titanosaur	rib fragment	17.4	5.3	359
titanosaur	rib fragment	25.3	2.2	30
titanosaur	rib fragment	42.3	3.3	42
titanosaur	rib fragment	11.6	4.6	28
titanosaur	rib fragment	26.6	4.2	212
titanosaur	rib fragment	11.3	7.2	348
titanosaur	sacral vertebrates	32.1	14.2	346
titanosaur	rib fragment	13.6	1.6	252
titanosaur	rib fragment	22.0	13.5	252
titanosaur	rib	44.7	11.4	272
titanosaur	flat bone of the basin	39.7	15.2	314
titanosaur	flat bone of the basin	36.7	17.3	254
titanosaur	hindlimb piece	18.9	14.6	230
titanosaur	tail vertebra	11.3	2.0	269
titanosaur	tail vertebra	4.0	2.3	308
titanosaur	tail vertebra	5.1	3.5	244
titanosaur	tail vertebra	4.2	1.0	287
titanosaur	tail vertebra	7.1	3.2	11
titanosaur	-	12.1	4.2	260
titanosaur	-	16.3	4.6	254
Titanosaur (Eva ends here)	-	11.2	3.4	44
rhabdodon		21.1	4.8	342
rhabdodon		29.2	11.7	293
rhabdodon		17.3	5.7	276
rhabdodon		7.4	6.3	276
rhabdodon		14.2	6.0	272
crocodile		27.4	4.4	304
crocodile		17.8	3.9	42
crocodile		2.2	0.6	66
crocodile		1.9	0.8	82
-		10.0	2.2	64
-		64	20.4	296

-		50.5	7.6	18
-		28	6.6	72
-		27.4	3.1	304
-		9.3	4.4	218
-		4.8	5.3	18
-		2.0	3.4	50
-		2.7	6.0	50
-		10.0	1.6	290
-		32.0	9.0	44
crocodile		36.0	8.2	244
crocodile		47.0	9.7	283
crocodile		33.0	9.8	221
titanosaur		68.2	9.3	259
rhabdodon		20.0	4.6	38

Appendix 2

The following diagrams show the mapped sections of Spring Creek that were used for the model experiments:

