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Franco-American renewed research at the Late Villafranchian locality of Senèze (Haute-Loire, France)

With 11 figs

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Abstract

The fossil site of Senèze, located in the Auvergne volcanic province of the French Massif Central, is well-known for its mammalian fauna and its role as the reference locality for the Late Villafranchian time interval, an important phase in the evolution of the fauna of Europe. This site is a filled-in volcanic explosion-crater lake (maar) where fossils are found in volcano-clastic sediments interfingering with lacustrine deposits at the lake margin. The Senèze mammals are generally considered to date between 2.2–1.5 Ma, but some authors have argued that this assemblage is not unitary, rather composed of two associations of different age. Moreover, little has been published about the geological setting or the processes of site formation. Our Franco-American research project, co-directed by the three first authors since 2000, is re-examining Senèze for the first time in 60 years. The team effort has three main goals: 1) to clarify the local geology (stratigraphy, mineralogy) of this complex site and determine the taphonomic processes involved; 2) to utilize a combination of methods (ESR and argon dating; tephrochronological and paleomagnetic correlation) to definitively establish the age of the site and its fauna; and 3) to collect additional mammalian fossils (especially of rare animals such as carnivores, primates and rodents) and samples of the non-mammalian biota, including vertebrates (e.g., birds and fishes), terrestrial and lacustrine invertebrates, pollen and diatoms from known points within the revised and dated stratigraphy. Several partial skeletons which appear devoid of carnivore disturbance have been recovered, and a new taphonomic hypothesis is proposed to explain this pattern. Some preliminary argon dates are presented for levels below the fossil mammals, while preliminary ESR and paleomagnetic results agree with an age broadly near 2 Ma. Pollen collected *in situ* and from coprolites allows a first step toward paleoenvironmental reconstruction

Key words: Villafranchian, Pliocene, mammals, geochronology, taphonomy, maar

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History of study

The hamlet of Senèze is located in a small depression between the villages of Domeyrat and La Chomette, near the source of a tributary of the Sénouire river, which flows in turn into the Allier (fig. 1). This depression is actually a Pliocene maar, filled by a lake which was progressively sedimented during the Villafranchian. The presence of fossil mammals at Senèze was first signaled by BOULE (1892). Over the next several decades, numerous fossils were collected, the majority deriving from land belonging to a local farmer, P. PHILIS, who sold the specimens he found. His principal clients were the Geology Laboratory of the University (Faculté des Sciences) of Lyon and the Museum of Natural History of Basel (Switzerland). The bulk of the collection dates to the years before World War I (DEPÉRET & MAYET 1911) and to the 1920s (SCHAUB 1922, 1923). STEHLIN (1923) and SCHAUB (1941, 1943–44) published the earliest syntheses of the Senèze fauna, based on the Basel collection. R. MASSON [(1943 unpublished) : «Le gisement de Mammifères de Senèze». Mémoire de DES Faculté des Sciences, Université Lyon I, 28 p.] summarized the Lyon collection, a few of whose specimens had been individually published earlier (DEPÉRET et al. 1923, DEPÉRET 1929, ROMAN & DARESTE DE LA CHAVANNE 1931, AZZAROLI 1952). In the 1950s, J. ROGER and his colleagues from the National Museum of Natural History in Paris undertook several field seasons at Senèze [ROGER 1954; also P. BRÉBION, P. CALAS, J. DROT, S. PIMIENTA-FRENEIX & L. NAZEMI (1953, unpublished manuscript in the archives of the Institut de Paléontologie, Muséum national d'Histoire naturelle, Paris): "Le gisement villafranchien de Senèze [Haute-Loire]", 5 p.]. Early in the 1960s, C. GUTH briefly sought fossils there (GUTH 1975: fig. 3), but his results were never published in detail, other than GUÉRIN'S (1980) study of a juvenile cranium of *Dicerorhinus etruscus* housed at the University of Poitiers.

In 1962, P. GRANGEON (1962, ELHAÏ & GRANGEON 1963) studied a 100 m core drilled into the maar by a company seeking to exploit minerals. A second core, 175 m long, was taken in 1965 and supported studies of diatoms (EHRLICH 1968; see below), sedimentology (PELLETIER 1968), palynology (ELHAÏ 1969), and a fossil fish (GAUDANT 1975). The last 20th century field work at Senèze was undertaken in 1991 by J. COUTHURES [1989; also J. COUTHURES, D. ABLIN & D. HADJOUIS (1991 unpublished): "Sénèze (Haute-Loire): Rapport à la DRAC Auvergne sur les fouilles 1991", 55 p.].

In the current state of our knowledge, Senèze is a locality of exceptional paleontological wealth. It was selected as the international biochronological reference of the Late Villafranchian (MNQ unit 18) by HEINTZ et al. (1974) and GUÉRIN (1980); GUÉRIN & PATOU-MATHIS (1996) considered it typical of the Early Pleistocene. In fact, its chronological relationship to the Pliocene-Pleistocene boundary is one of the current points of contention surrounding Senèze.

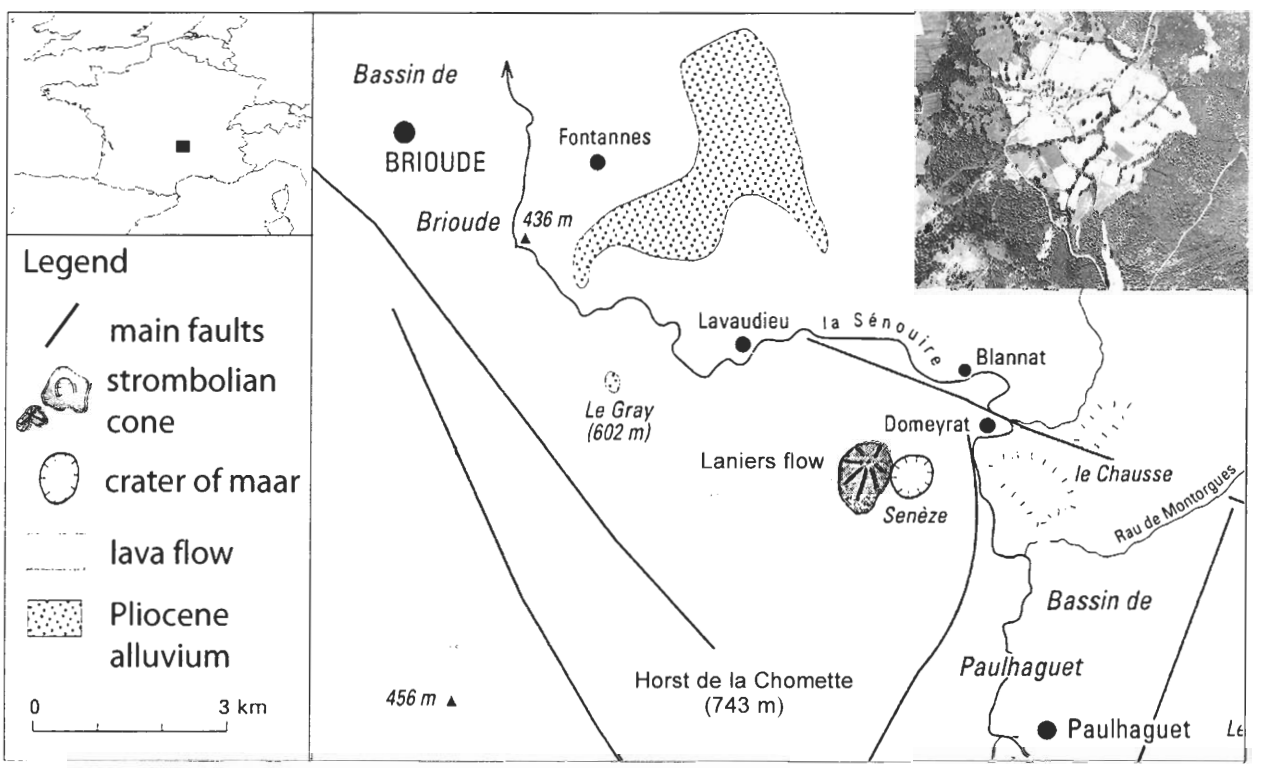

Fig. 1: Location of Senèze. Sketch map of the region between Brioude and Paulhaguet, Haute-Loire (Auvergne), central France with selected geological structures. Left inset: location of main map within France; right inset, section of air photo showing Senèze crater and fields. From GAUTHIER & PASTRE (2004) and air photo IGN 1995-FD-43-63/300, no. 633.

Fossils from Senèze

Fauna

Review articles by Stehlin (1923), Schaub (1943–44), Masson (1943), Devis (1970), and Heintz et al. (1974) listed about 30 species of mammals and a dozen birds. Numerous more specialized studies (Kormos 1931, Ballesio 1963, Prat 1964, 1968, 1980, Heintz 1964, 1966, 1968, 1970, 1972, 1974, Guérin 1965, 1980, Martin 1973, Chaline & Michaux 1974, Delson & Plopsor 1975, Gaudant 1975, Faure & Guérin 1979, 1984, Eisenmann 1979, 1980, 1981, 1984, Turner 1987, Duvernois & Guérin 1989, Duvernois 1990, Mourer-Chauviré 1990, Torres Pérez Hidalgo 1992, Guerrero-Alba & Palmqvist 1997, Anton & Werdelin 1998, and Maul 2004) have made additions or corrections to this list, which now includes:

Mammals

Among the 34 species of mammals now identified in the Senèze collections, 14 taxa (genera, species and subspecies) were first defined for Senèze samples. Of these new taxa, 12 (3 genera, 7 species and 2 subspecies) are still considered valid; these are indicated by * in the list that follows.

Primates

Cercopithecidae: *Paradolichopithecus arvernensis** (Depéret, 1929); *Macaca sylvanus* cf. *florentina* (Cocchi, 1872).

Proboscidea

Elephantidae: *Mammuthus meridionalis* (Nesti, 1825).

Perissodactyla

Equidae: *Allohippus stenonis senezensis** Prat, 1964; *Equus bressanus* Viret, 1954; *E. stehlini* Azzaroli, 1965 (see below for new material).
Rhinocerotidae: *Dicerorhinus etruscus etruscus* (Falconer, 1859).

Artiodactyla

Suidae: *Sus strozzii* Meneghini & Major, 1881.
Cervidae: *Croizetoceros ramosus minor** Heintz, 1970; *"Cervus" philisi* philisi* Schaub, 1941; *Eucladoceros ctenoides ctenoides* (Nesti, 1841); *Libralces* gallicus** Azzaroli, 1952.
Bovidae: *Gazellospira torticornis* (Aymard, 1854); *Procamptoceras* brivatense** Schaub, 1923; *Megalovis* latitrons** Schaub, 1923; *Gallogoral* meneghinii* (Rütimeyer, 1878); *Leptobos furtivus** Duvernois, 1989; *Leptobos etruscus* (Falconer, 1859); *Pliotragus ardeus* (Depéret, 1884); *Ovis* sp.

Carnivora

Canidae: *Nyctereutes megamastoides* (Pomel, 1842); *?Vulpes alopecoides* Forsyth Major, 1877; *Canis senezensis** Martin, 1973.
Ursidae: *Ursus etruscus* Cuvier, 1823.
Hyaenidae: *Pachycrocuta perrieri* (Croizet & Jobert, 1828); *Euryboas lunensis* (Del Campana, 1914).
Felidae: *Acinonyx pardinensis* (Croizet & Jobert, 1828); *Homotherium crenatidens* (Fabrini, 1890); *Megantereon cultridens* (Cuvier, 1824).

Lagomorpha

Leporidae: *Oryctolagus* cf. *lacosti* (Pomel, 1853).

Rodentia

Arvicolidae: *Mimomys pliocaenicus / ostramosensis*-group (large), *M. pitymyoides*-group (small); following Maul (2004)
Sciuridae: aff. *Eutamias* sp.
Castoridae: indet. (see below for new material)

Birds

Mourer-Chauviré (1990) recently reviewed the peacock *Pavo bravardi*, but she considered all other bird taxa cited at Senèze to be badly in need of major revision.

Ciconiiformes: *Ciconia* sp.
Anseriformes: Anatidae indet. (several)
Galliformes: *Pavo bravardi* (Gervais, 1849); *Alectoris barbara* (Bonnaterre, 1790); *Lyrurus tetrix* (Linnaeus, 1758).
Gruiformes: *Anthropoides virgo* (Linnaeus, 1758).
Coraciiformes: *Corvus hungaricus* Lambrecht, 1916.
Strygiformes: *Bubo* sp.
Passeriformes: indet.

Other animal taxa are in an even lesser state of understanding, with the following recorded in the literature:

Anapsida, Testudines

Chelonia indet.

Amphibia

Urodela indet.

Actinopterygii, Teleostei

Tinca sp.

Mollusca

Bivalvia indet.
Limnea sp.

Crustaceamorpha

Ostracoda indet.

Flora

ELHAÏ (1969) presented a detailed analysis of the upper 120 m of the 1965 core. He reported that the lowest 52 m of the core was composed of solidified (welded?) tuff and crater debris; this was overlain by 43 m of fluvio-lacustrine sediments, in turn underlying 80 m of diatomaceous clay, with a sandy layer between 28–22 m below the top. ELHAÏ described a general alternation between two main plant assemblages: a warm-climate forest of thermophile, generally leafy trees, both local and exotic; and a cooler-climate forest of conifers mixed with herbs, the latter sometimes expanding to cover most of the ground surface. He divided the core into a series of phases dominated by one of these two assemblages: from 120–94 m, a temperate phase with poorly diversified vegetation might signify the first "recovery" after a significant cold interval (for him, perhaps the start of the Pleistocene); this was followed by a cool and humid phase from 94–76 m. Between 75–43 m came the interval richest in thermophile plants and poorest in herbs, within which the earlier part was humid and temperate, while the later part was humid and cool; between 43–29 m, a cold and relatively dry phase occurred; and from 24 m to the top of the core came a complex alternation of three cycles, each with a temperate-humid subphase followed by a cool or cold subphase. BOUT (1975) suggested that these Senèze warm phases might be among the latest in the Villafranchian interval. ABLIN (in COUTHURES et al. 1991) reanalyzed the non-arboreal pollen from ELHAÏ's diagrams and compared her results to those from Ceyssac (ABLIN unpublished). She considered that Senèze documented an alternation of deciduous forest (without many conifers but with rare Mediterranean taxa) and open steppe with *Artemisia* and Poaceae. She correlated the upper part of her pollen diagrams with the Eburonian, rather than with the Waalian (as had ELHAÏ).

In studying the diatoms from this core, EHRLICH (1968) distinguished three main intervals: from 107–97 m, littoral species of diatoms were more common than planktonic ones; between 96–20 m, littoral, benthic and epiphytic taxa disappeared to be replaced by a euplanktonic species; and from 19 m up, the littoral forms again dominated. BOUT (1970) interpreted these three phases to imply an early period of slow lake filling, with shore diatoms washed in; followed by a deep lake where plankton flourished; and finally an interval when the lake was filling with sediment and only shallow-water diatom species flourished. EHRLICH (1968) also estimated that the number of laminations in the diatomite (which she interpreted as annual) was probably between 2–3 x 10^5.

Problems necessitating further study

Senèze has yielded a rich and remarkably well-preserved mammalian assemblage, which is clearly of Villafranchian age but younger than that from the locality of Saint-Vallier [see, e.g., GUÉRIN & PATOU-MATHIS 1996; the special issue on Saint-Vallier edited by FAURE & GUÉRIN (2004) has summarized current knowledge on that locality]. However, the geology of Senèze is poorly known, its exact chronological position within the 2 million year span of the Villafranchian is unclear, the homogeneity of the fauna itself has been questioned, and nothing is known of its taphonomy. There was much discussion of Senèze and its problematic fauna at the 1999 workshop on Palearctic mammalian evolution and the new Late Pliocene Vatera locality on Lesvos (Annales Géologiques des Pays Helléniques, vol. 39A, 2002). At that meeting, DELSON, FAURE & GUÉRIN agreed to investigate the possibility of reopening Senèze to new analyses in hopes of clarifying some of these questions.

Geological problems

BOUT (1960, 1970a, b, c, 1972, 1975) discussed the geology and stratigraphy of numerous French Villafranchian localities in the Velay and the Allier valley. In 1970, he described the geological setting of the Senèze maar and the sequence of events which formed it. As he mapped it, the site is a large scoria cone to the (north)west of a deep infilled maar, about 500 m across. He considered that the cone formed early, but this was questioned by COUTHURES (1989). Later studies by PASTRE and others (see DEBARD & PASTRE 2004) confirm that the flow antedated the formation of the maar and reveal that the volcanic system consists of the maar crater and two contemporaneous scoria cones: the Pié de Charenty which reaches an elevation of 754 m and is located about 600 m northwest of Senèze, and a lesser peak (728 m) about 300 m southwest of the former. The Pié de Charenty produced a flow of basanite (the Laniers flow) which extended first toward the southwest, then the northwest, covering the gneiss basement. Phreatomagmatic tuffs and breccias are found on the heights to the southwest and especially west of Senèze (DEVIS 1970). The Pié de Charenty is not a massive scoria cone as BOUT argued, but rather at its summit there is a small outcrop of welded scoria (slag) resulting from lava-fountain activity.

As explosive (phreatomagmatic) activity died down, the maar then slowly filled in with lacustrine deposits, up to 123 m thick. The lake water depth varied, but was probably always less than 40 m, according to EHRLICH's (1968) study of diatoms. Finally, offwash slope deposits built up on the inner (especially western) slope of the crater.

Bout (1970: and also Couthures 1989) reported that the mammalian fauna was derived from the upper levels of the maar infilling as well as from the slope deposits.

Geochronological problems

Age estimates for Senèze have ranged between roughly 2.2–1.5 Ma. Based on the fauna, Heintz (1968) and Guérin (1980) suggested 1.5 Ma as a rough "guesstimate". Bout (1970) combined Ehrlich's (1968) idea of 300,000 annual layers in the diatomite with an early estimate of 1.9 Ma for the Laniers basanite to suggest that the upper levels of the maar might have dated to 1.6 Ma and the fauna perhaps to 1.5 Ma. Prévot & Dalrymple (1970) gave a whole-rock potassium-argon date of 2.3 ± 0.15 Ma for samples of the Laniers flow, while Couthures (1989) reported a roughly comparable date of 2.48 ± 0.06 Ma. Fouris et al. (1991) cited a personal communication from M. Baubron indicating a younger age of 2.14 ± 0.1 Ma.

Both Prévot & Dalrymple and later Couthures reported a reversed polarity for the Laniers flow, correlated to the lower Matuyama. Prévot & Dalrymple (1970) also reported paleomagnetic data for the upper 132.5 m of the 1965 core. The analyzed section was entirely reversed, except for a 5–10 m normal zone from 17.5 to somewhere between 23.5 and 28 m below the top of the core; two other short normal intervals 95 and 46 m below the core top were dismissed as modern imprints. Prévot & Dalrymple suggested that the normal magnetozone might correlate to the "Lower Olduvai" which they thought dated ca. 2.1 Ma.

Delson (1973) and Delson & Plopsor (1975) re-interpreted these geochronological elements to suggest that the normal magnetozone was too short to represent the Olduvai subchron (now known to be nearly 0.2 Ma long) if the whole core documented ca. 0.3 Ma. Instead, it was suggested to correlate with the Réunion (which was probably what Prévot & Dalrymple had meant), implying an age for the fauna closer to 2 Ma.

Numerous other authors have recently commented on the relative age of the Senèze local fauna (or faunas), or have assigned it to a place within the sequence of Villafranchian faunas. For example, in a survey of French Plio-Pleistocene assemblages, Bonifay (1992) charted Senèze (as a single fauna) at 1.6 Ma in the Late Villafranchian, younger than St. Vallier (at 1.9 Ma) and immediately between Olivola and Tasso. Azzaroli et al. (1997: 152) estimated that a "date between 2.0 and 1.8 Ma is the only plausible age for the fauna of the Senèze maar deposits", but continued to argue for a second, significantly younger assemblage mixed in with the older fossils (see below). Chaline (1997), on the other hand, placed Senèze in his *Mimomys pliocaenicus / Allophaiomys deucalion* biozone, with an estimated age of 1.8–1.4 Ma. Sardella et al. (1999) illustrated Senèze at ca. 2.1 Ma, just younger than the Reunion Subchron, but without discussion; a similar placement was indicated by Kotsakis et al. (2003). Maul (2004) reported that morphometrics of the rare Senèze arvicolid lower molars suggested a similarity to Central European localities near the Plio-Pleistocene boundary, ca. 2.0–1.7 Ma.

Roger et al. [2000; also Roger (2000 unpublished): «Datations 40Ar/39Ar des niveaux volcaniques intercalés dans des séquences sédimentaires lacustres et marines, pléistocènes à messiniennes: implications paléoenvironnementales». Thèse Doctorat Univ. Aix-Marseille III, Faculté des Sciences et Techniques de Saint-Jérôme, 246 p.] confirmed Delson's (1973) suggestion: a thin normally magnetized tephra layer in a short core taken in 1989 was dated at 2.10 ± 0.01 Ma. Based on estimated sedimentation rate, an age of 2.09 Ma was assigned to the top of the Réunion normal subchron. The Senèze mammalian fauna (about 50 m higher altitudinally) would then presumably date younger than this, but by how much is unclear. Rather than representing an early Pleistocene recovery, the lowest floristic assemblage in the Senèze core might reflect warming after the 2.6–2.4 Ma global cold phase (see Vrba 1995).

Palaeontological problems

The age of the Senèze fauna is thus the subject of international debate. Also in question is the homogeneity of the assemblage, as well as the mode of site formation and the paleoenvironment. Many of these questions relate back to the exploitation of the locality (and various individual findspots) by an amateur who seems to have closely guarded the location of his finds. There is no stratigraphic detail or other contextual information associated with any of the material in the collections of the Naturhistorisches Museum in Basel or the Université Claude Bernard-Lyon I.

There is some concern that this assemblage is not unitary, but instead is composed of two associations of different age. In their list of large mammals from this and other French Villafranchian sites, Heintz et al. (1974) assumed a single unified assemblage for Senèze. Azzaroli et al. (1988) proposed the hypothesis of two faunules on the basis of an analysis of Schaub's (1943–1944) faunal list plus original studies; these authors, however, did not cite (and may not have been aware of) the revision by Heintz et al. (1974). Of the taxa listed in table 2, Azzaroli et al. (1988: 82) considered that *Libralces gallicus*, *Megalovis latifrons* and *Equus bressanus* "clearly point to a late Villafranchian age." They also included in that category *Canis arnensis* and "a small equid which may possibly be *Equus stehlini*." Azzaroli et al. (1988) suggested that the larger and more speciose assemblage, presumably from the upper levels of the maar (see below) might date to ca. 2 Ma, in their middle Villafranchian, while the less extensive faunule might date ca. 1 Ma, near the end of the Villafranchian as they conceived of it. Couthures (1989) on the other hand, suggested a possible mixture of faunas of a single age but different environments, resulting from mass asphyxia due to the leakage of some volcanic gas.

Moreover, although some mammalian taxa are abundantly represented, others are known only from a few fragmentary specimens: the two primates, *Equus stehlini*, *Libralces gallicus*, *Megalovis latifrons*, *Ovis* sp., *Procamptoceras brivatense, Pliotragus ardeus*, *?Vulpes alopecoides* and *Canis senezensis*. New specimens of any of these would be important additions to the Senèze fauna. Finally, micromammals have never been the subject of systematic study, and (as noted above) the birds are in need of revision. Other than one fish (GAUDANT 1975), all the lower vertebrates require identification, and palynological study of the vertebrate horizon(s) remains to be undertaken.

Current work: goals and preliminary results

A new program of collaborative research at Senèze was begun in 2001 under the direction of M. FAURE, C. GUÉRIN and E. DELSON. Our goals were:

1) to establish a detailed stratigraphy (and sedimentology) of this complex locality, where fossils have been recovered from both lacustrine and slope deposits whose relationships are unclear; to clarify the origin of the fossils themselves, whether from one or several distinct horizons; and to understand the taphonomic origin of the fossil assemblage;
2) to apply multiple dating methods to obtain chronometric ages for the site and its fossils: $^{39}Ar/^{40}Ar$ or K-Ar for the underlying basalt and any tephric horizons above that; ESR for fossil dental enamel and perhaps for volcanic products, and magnetostratigraphic correlation;
3) to recover additional fossils, especially of rare taxa, in clear stratigraphic position, to collect samples for palynological analysis and to reconstruct the paleoenvironment; and
4) to clarify the pattern of co-occurrence for the mammals combined into a unified faunal list and to compare the Senèze fauna with those of other European Villafranchian assemblages, such as that from Saint-Vallier (Drôme, France) and examine problems of age and faunal replacement.

Moreover, Senèze could serve as a teaching venue for students in paleontology and geology from France and other nations.

After a preliminary visit in 2000, field seasons were undertaken in 2001–2005, combining geological trenching, excavation for fossils and searching for new findspots. Land within the Senèze "crater" has been subdivided into more than 200 numbered parcels, of which the more central are used for agriculture and/or pasturage by descendants of several originally resident families mentioned by DEPÉRET & MAYET (1911) as having fossils on their

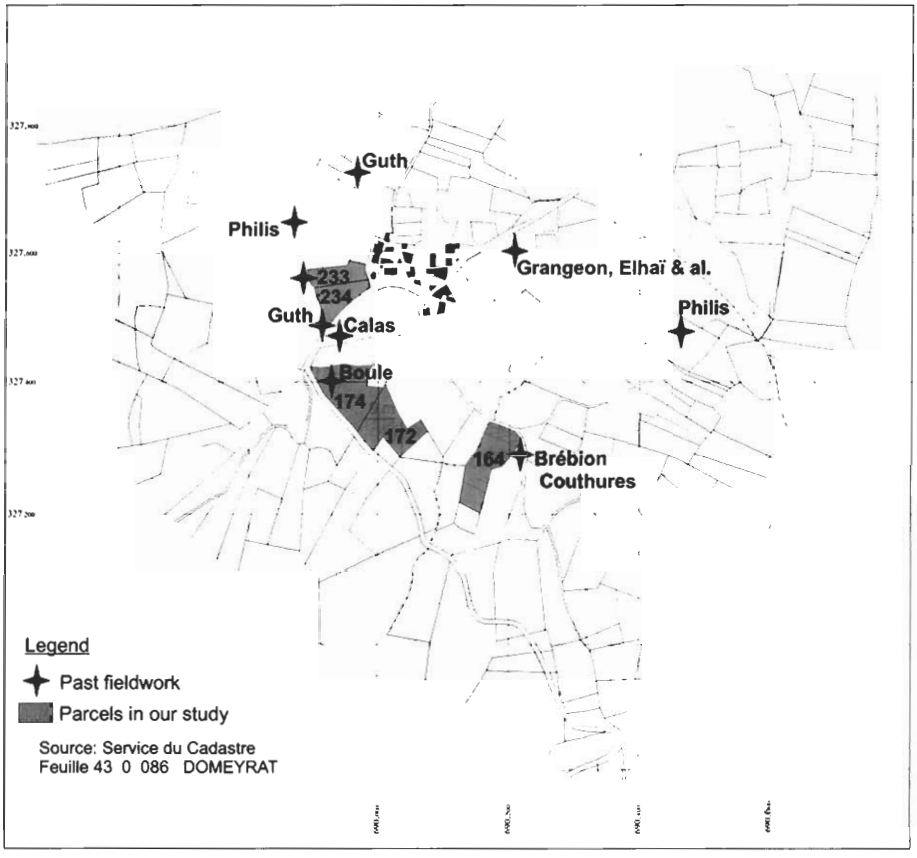

Fig. 2: Cadastral map of parcels in the central part of the Senèze crater, with locations of previous and current fieldwork and coring. Parcels 233–234 trenched (T1–3) in 2001, 233 excavated in 2003–2005; parcel 174 trenched (T4) in 2003; parcel 172 trenched (T5) and partly excavated in 2004–2005; parcel 164 yielded surface finds to CONSIGNY & SERRE.

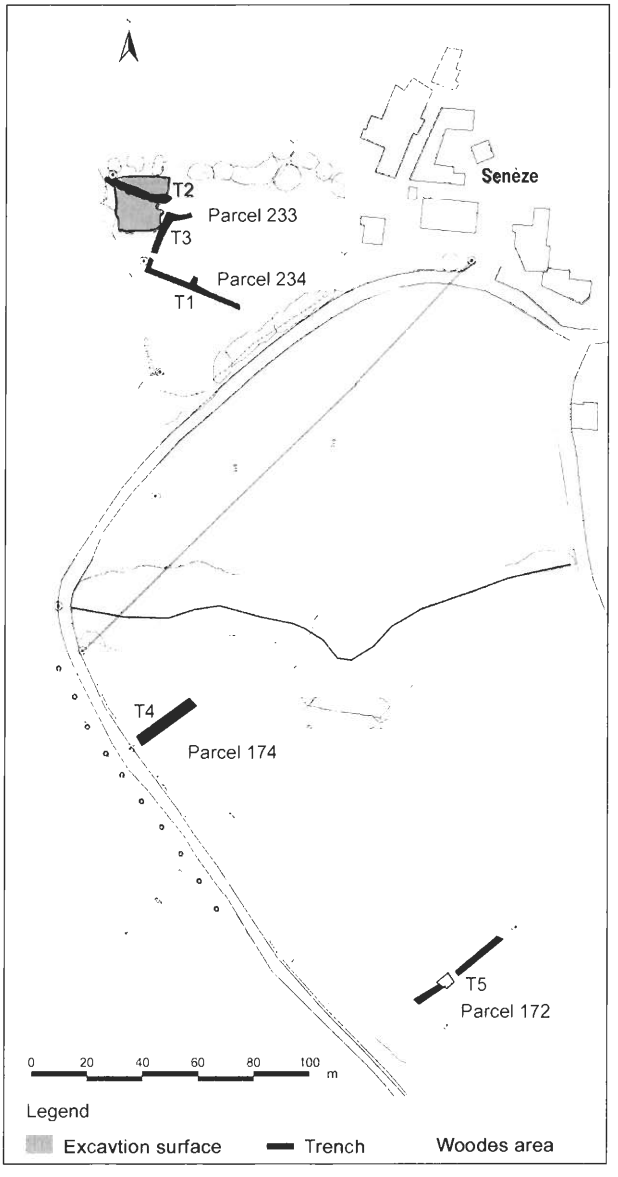

Fig. 3: Topographic drawing of area studied in 2001–2004, with contour lines (interval 1 m), trenches and excavated surfaces; 2005 equid skeleton recovered at NW end of T5.

Fig. 4: Trench 5: below, view of upper part of trench with team members working on "step" under sunshade; above, view from "step" into lower part of trench.

property; several landowners provided permission for the team to work on their parcels (fig. 2). The land surface in the middle of the infilled maar, at the site of the several core boreholes, lies at 590 m elevation. In 2001, trenches 1–3 were excavated with the aid of a backhoe in and near parcel 233, centering on 620–625 m (fig. 3; see also fig. 7). This parcel was extensively excavated for fossils in 2003 and 2004 (fig. 10). A large trench (T5) some 11 m in vertical extent (613–624 m) was cut in parcel 172 during the 2004 season; the upper segment is separated from the lower by a bench or step, where backhoe work ceased when a partial cervid cranium was exposed (figs. 3 and 4). In both the trenches and the exposed surfaces, in addition to excavation of macromammalian remains, numerous samples were collected for analyses of sedimentology, mineralogy, tephrostratigraphy, palynology, micromammal screenwashing, magnetostratigraphy and radiometric dating. Study of all these collections is in progress.

Precise topographic mapping at a scale of 1:500 with contour intervals of 1 m was carried out successively by F. Parenti, L. Aprile, F. Candeu & co. and A. Monguillon

using both a laser alidade (total station) and a mechanical alidade and planetable. Using the ArcView program (ESRI Corp.), a GIS framework was developed which allows the incorporation of each new sampling point or fossil, along with metadata on its characteristics. Similarly, a database of finds has been recorded in Microsoft Excel by A. VALLI, and E. DELSON. The team submits annual reports to the authorizing agency (Service régional de l'Archéologie–DRAC Auvergne) where basic results are documented [e.g., M. FAURE, C. GUÉRIN, E. DELSON and others (2004 unpublished): "Rapport 2004 à la DRAC Auvergne sur l'opération de fouille programmée annuelle dans le gisement paléontologique villafranchien supérieur de Senèze à Domeyrat, Haute-Loire", 47 p.], while a brief summary of work through 2003 was presented by FAURE et al. (2004).

Results

a – Geology

In trench 5 (parcel 172), DEBARD has distinguished four main sedimentary units, with a mean inclination of 20°. The first three correspond to slopewash deposits, while the fourth is lacustrine in origin. The macrofaunal elements from T5 derive only from the slope deposits (fig. 5).

In parcel 233, DEBARD & PASTRE (2004) reported a rather consistent arrangement of deposits, passing downslope from offwash slope deposits to those of lacustrine origin. The highest lacustrine beds overlie and interfinger with slopewash layers with a fine or coarse granulometry, emplaced as a result of solifluction in some cases and debris flows in others. These lake beds are in turn overlain by generally coarse layers, linked to a major instability or collapse of the slope. The observed deformation structures relate to both extensional (normal faults, stretching) and compressional (folds, *boudinage*) factors. The fossils are found in both lacustrine and offwash slope deposits (fig. 6).

PASTRE (in DEBARD & PASTRE 2004) has demonstrated the presence of several tephra layers derived from the Mont-Dore stratovolcano within the Senèze fossiliferous sequence. Based on mineralogical analysis, four tephra types corresponding to distinct ashfalls have been distinguished so far. The first three derive from trachytic airfalls typical of Mont-Dore eruptions. The fourth is uncommon, with a mineralogy which corresponds to a hydroclastic tephritic emission, comparable to those found in the northern zone of the stratovolcano. At the present state of analysis, none of these tephra types corresponds

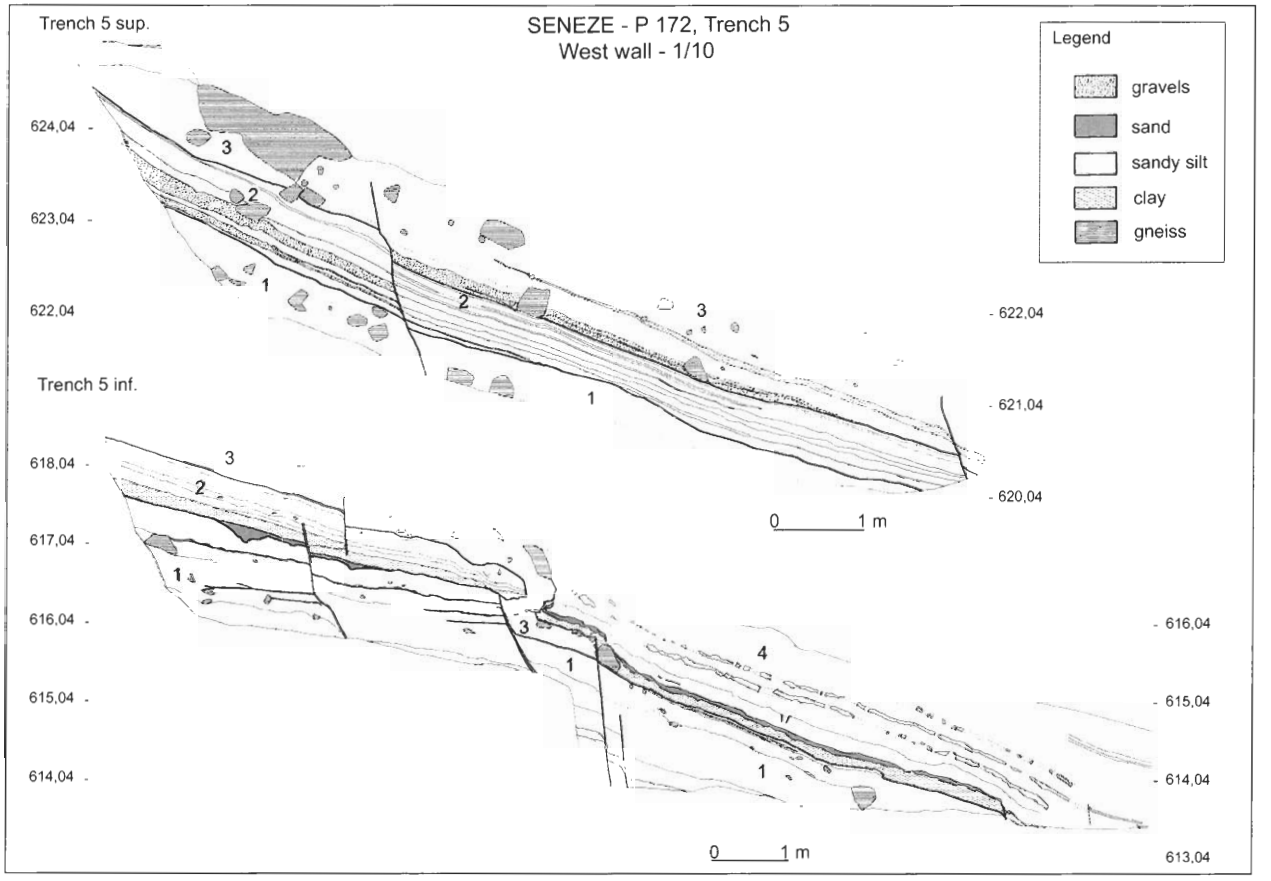

Fig. 5: Stratigraphic sections of Trench 5, parcel 172, west wall, from originals prepared by DEBARD at a scale of 1:10. Above, superior portion; below inferior portion (separated by "step", see fig. 4). Numbers indicate four main stratigraphic units recognized by DEBARD; elevations in m above sea level.

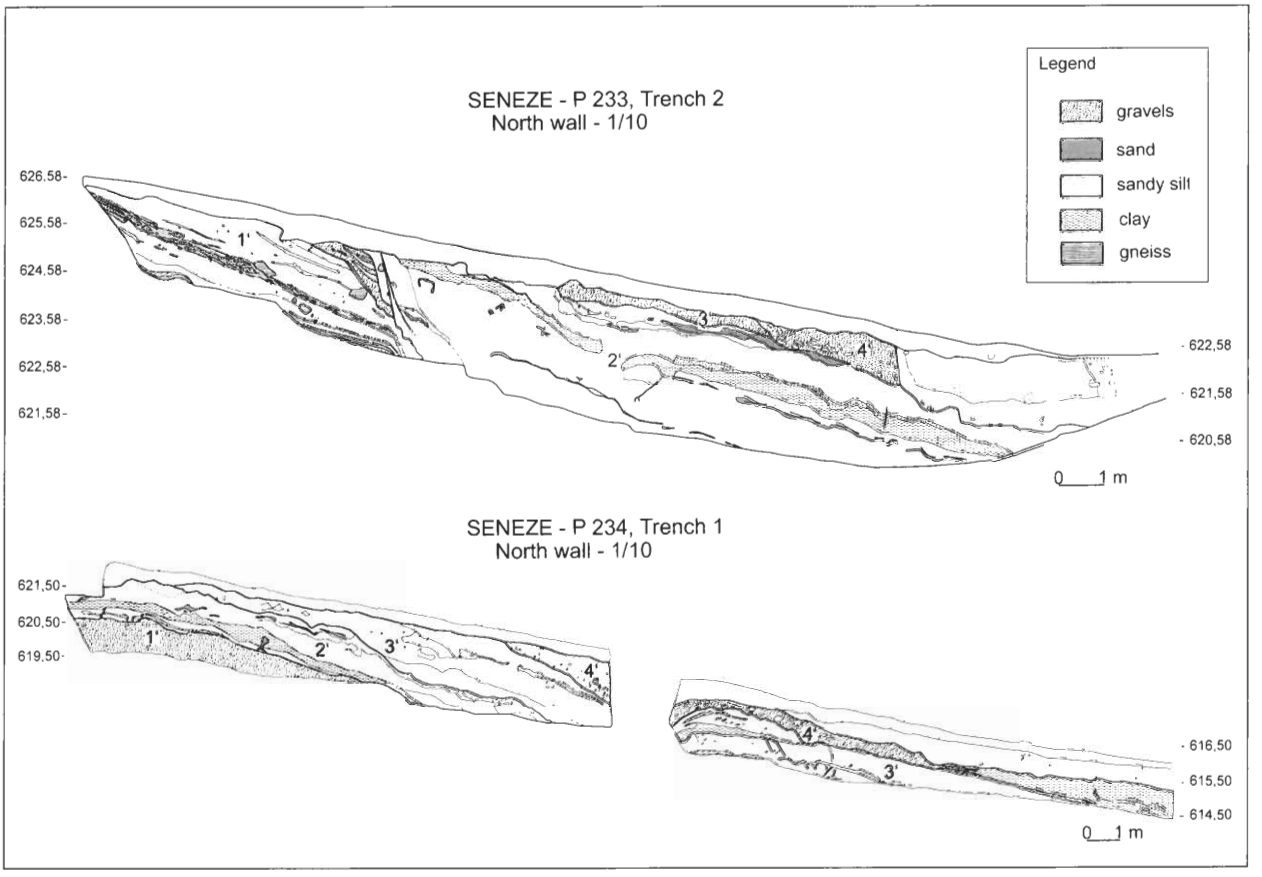

Fig. 6: Stratigraphic sections from originals prepared by DEBARD at a scale of 1:10. Above, Trench 2, parcel 233, north wall; below Trench 1, parcel 234, north wall. Numbers indicate four main stratigraphic units recognized by DEBARD; elevations in m above sea level.

to those recognized in the fossiliferous sequences of the Devès region, nor to the tephra layer identified in the upper part of the Senèze lacustrine core by ROGER et al. (2000). Mineralogical comparison of the tephra layers located in parcel 233 and T5 is in progress. Renewed coring in different sectors of the valley has begun to yield additional information which may lead eventually to the possibility of direct correlation of the fossiliferous layers with those in the deep cores drilled decades ago.

Geochronological studies begun in 2001 are still under way. SWISHER has obtained a preliminary result of 2.35 Ma on a sample of the Laniers basanite flow newly collected by PASTRE; analytical details are forthcoming, but this date agrees well with and may refine previous estimates. SWISHER, E. GUILLOU and S. SCAILLET are analyzing splits of the several tephra layers using the argon/argon approach. One such layer located below a fault which in turn underlies the rhinocerotid skeleton collected in Trench 2 (see below) yielded a preliminary date (SWISHER) of 2.1 Ma. This is equivalent to the age obtained by ROGER et al. (2000) on the tephra layer in the 1989 core, located some 50 m lower altimetrically. Analytical details are awaited on this and other dating experiments in progress.

ESR analysis of enamel from Senèze mammalian teeth is proceeding under the direction of BLACKWELL & SKINNER. The approximate age of Senèze is at the older margin of generally accepted ESR dates, and in order to extend the method into this time interval, a range of techniques has been adopted. We collected samples to obtain radiation dose levels by three complementary methods: bulk sediment geochemistry, gamma-spectrometry, and TL dosimetry. The isochron analytic approach will be applied when possible. A blind test of previously collected specimens from Senèze and several other localities is in progress along with experiments on newly-recovered teeth from our excavations. Preliminary results confirm an age close to 2 Ma, but higher precision is desired, requiring additional irradiations. SEN collected samples for preliminary paleomagnetic analysis in 2001 (in parcel 233); these suggest the presence of a normal magnetozone high in the section, above mainly reversed sediments. Additional samples were collected in 2004 in trench 5 as well as both higher and lower in the parcel 233 sequence; these also reveal one or possibly two normal zones, but intercorrelation of all the profiles is still in progress.

b – Vertebrate Palaeontology

The following fossil material has mainly been recovered with precise stratigraphic location and is under study:

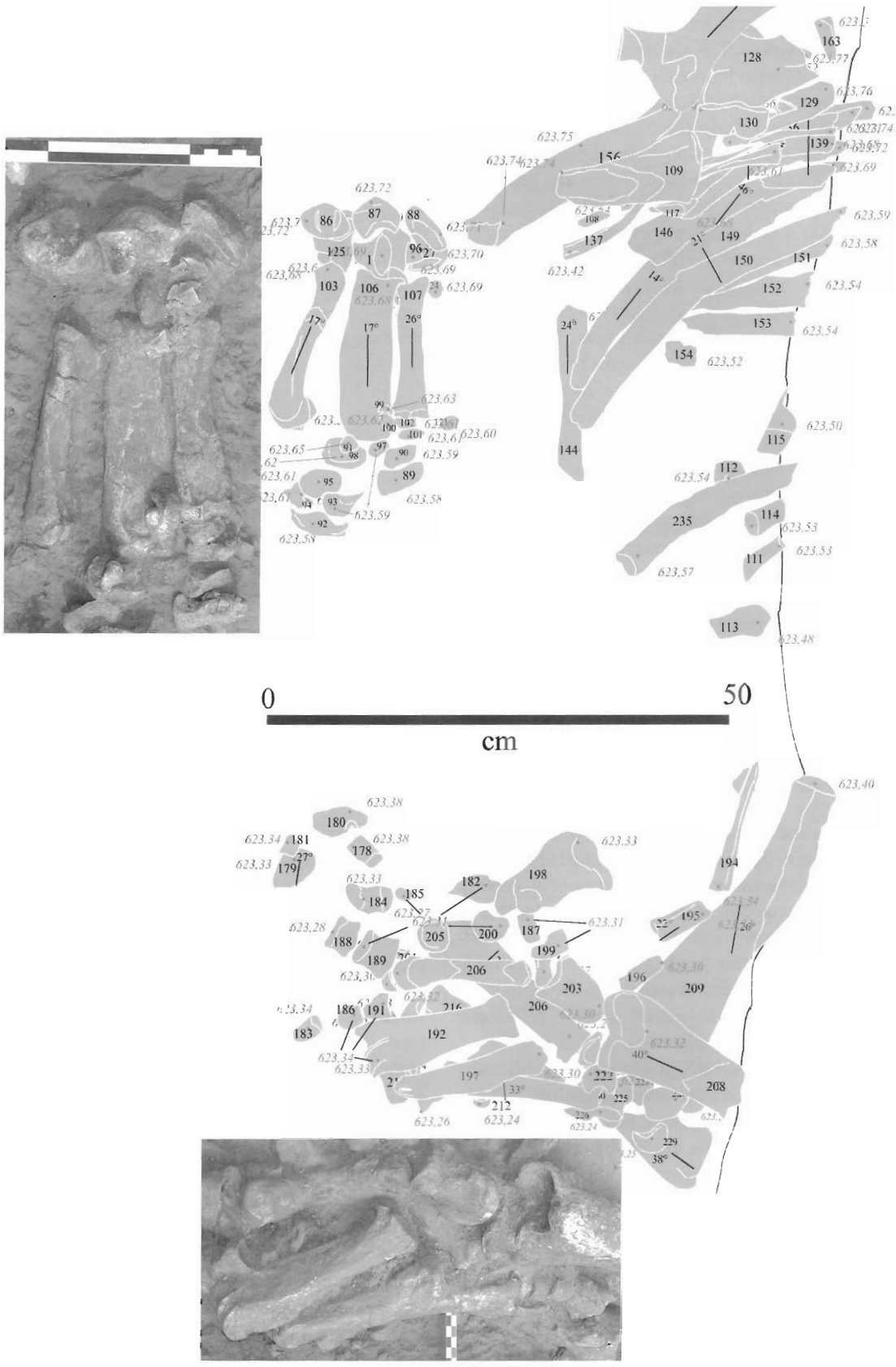

Fig. 7: Measured drawing of rhinoceros (*D. etruscus etruscus*) partial postcranium before removal from parcel 233 in 2001 season, with photographs of hind foot (below) and fore foot (above) near their drawn equivalents; smaller scale divisions (in photographs) in cm. Irregular thin line at left represent the edge of the trench, with some bones protruding above it.

Fig. 8: *Allohippus stenonis senezensis* partial hindfoot, with distal metatarsal and three phalanges (T5, parcel 172, 2004); smaller scale divisions in cm.

Carnivora

One fragmentary toothrow of the Perrier hyaena, *Pachycrocuta perrieri*.
One partial right mandibular corpus with p3-4 and an isolated right lower canine (probably of the same individual) of the rare cheetah *Acinonyx pardinensis*.

Perissodactyla

In trench 2 of parcel 233, a partial skeleton of the rhinoceros *Dicerorhinus etruscus etruscus* was recovered in 2001 (fig. 7), with additional remains of the same adult individual coming to light in 2003 and 2004. Most of the postcranium (especially the limb elements) is present, in addition to a fragmentary mandibular corpus with toothrow and an anterior fragment of nasal bone. Two metapodials of the same species were discovered in 2004 in T5. The Etruscan rhinoceros was probably one of the dominant large mammals at Senèze.

A distal fragment of metapodial of *Equus bressanus* was discovered on the surface in parcel 164 by A. Consigny and B. Serre, who transferred the specimen to us in 2002. This large horse is rare at Senèze.

In 2004, the distal half of the metapodial and the three phalanges of the hindfoot of a small horse, *Allohippus stenonis senezensis*, were recovered in anatomical connection in T5 (fig. 8).

In 2005, a nearly complete mostly articulated skeleton of the even smaller *Equus stehlini* (fig. 9) was recovered in the trench 5 area, at a level predicted by Debard to be fossiliferous based on the local sequence of strata. The taxonomic identifications of the equids are provisional, pending full study by V. Eisenmann; if supported by her analysis, the presence of two or three species in close proximity would militate against the hypothesis of Azzaroli et al. (1988) that it represents a younger faunal assemblage.

Artiodactyla

Various dental and pedal remains (often in connection) belonging to small- and medium-sized taxa of the two principal families of ruminants (Cervidae and Bovidae) have been recovered each season.

Fig. 9: *Equus stehlini* skeleton as excavated in parcel 172, 2005 scale: meter stick 2 1m showing 2 m between "E" symbols

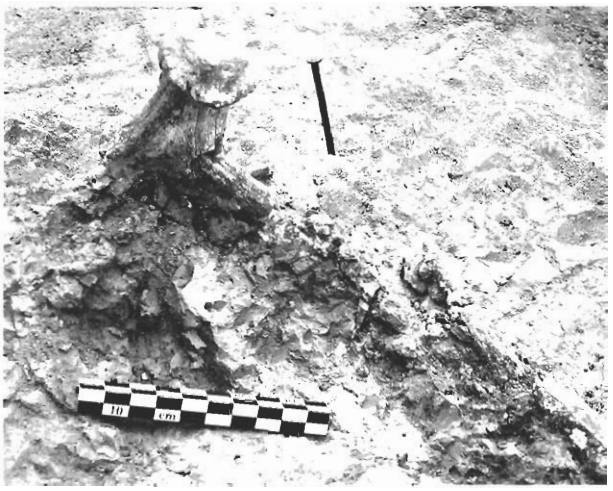

Fig. 10: "*Cervus*" *philisi*, from parcel 233, 2003, fragment of antler in vertical position in situ.

Numerous elements of the mid-sized cervid "*Cervus*" *philisi* (including mandibles, astragali and fragments of antler, of which one was in a vertical position with the crown uppermost; fig. 10) confirm that this deer was also common at the site.

Well-preserved remains of the large deer *Eucladoceros ctenoides* were recovered in 2004, including most of a postcranial skeleton in anatomical connection (in parcel 233) and (in T5) the posterior part of a cranium with antlers and another partial skeleton with face, mandible, pelvis and some long bones. The latter two were found only 2.5 m apart and in the same horizon but belong to different individuals.

Finally, a complete posterior cannon-bone of the large bovid *Leptobos etruscus* was discovered on the surface in parcel 164 by A. CONSIGNY and B. SERRE; in 2004, teeth of this species were found in T5.

Proboscidea

A large fragment (1.5 m long) of a tusk of the primitive mammoth *Mammuthus meridionalis* was recovered in parcel 233 during 2003.

Rodentia

An incisor of Castoridae, the first element of this family known from Senèze, was found in parcel 233.

One molar of *Mimomys* cf. *pitymyoides* was recovered from the same parcel. In order to seek further micromammals, MARTIN-SUAREZ and M. FREUDENTHAL have supervised the screen-washing of numerous sediment samples which are currently being searched for fossils. MAUL (2004) has reviewed the older Senèze collection of arvicolids and suggested that given the fragmentary nature of the known isolated teeth, it is better to group the larger form(s) as representatives of the *Mimomys pliocaenicus / ostramosensis*-group, while placing the smaller form(s) in the *M. pitymyoides*-group, rather than accepting the previous work of KORMOS (1931) recognizing the species *Mimomys pusillus* (MÉHELY, 1914); *M. pliocaenicus* FORSYTH MAJOR, 1902; and *M. newtoni* FORSYTH MAJOR, 1902.

Teleostei

Numerous fish vertebrae have been collected in parcel 233. Two blocks of sediment with associated remains of large fishes were extracted from the same parcel in 2003 and given to J. GAUDANT for study.

Coprolites

Ten coprolites probably attributable to hyaenas (see discussion of allocation in CHAME, 2003) were discovered in 2001 and 2002 near the rhino skeleton of parcel 233; they contain pollen which is reported below. Another coprolite (showing the typical shape and size of extant hyaenid feces) was discovered in T5 (fig. 11).

c – Palynology

Numerous samples were collected in the lacustrine sediments for analysis by ARGANT (2004). The richest sample contained only 63 pollen grains, with *Pinus* dominant (49 grains). Six other taxa present included *Betula* (birch) and 5 herbs (Poaceae, Cichorioideae, *Plantago*, *Rumex*, Rosaceae). The number of grains for each of these is too small to allow an interpretation of the vegetation cover.

However, four of the 10 carnivore coprolites proved richer. They yielded remains of 19 plant taxa: 11 trees, five herbs and one pteridophyte; this pollen may have been derived from airborne distribution settling onto prey or environmental surfaces or perhaps represents ingested items. The trees dominated, especially deciduous varieties, with 8 taxa – oak, beech, alder, linden, birch, hazelnut,

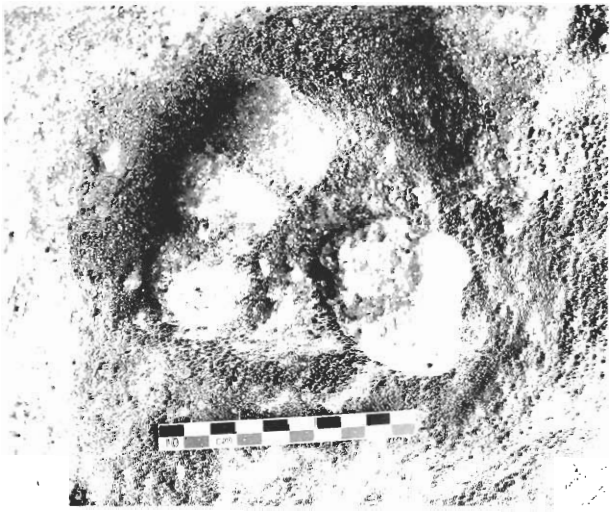

Fig. 11: Coprolite found in lower segment of T5 (parcel 172, 2004), in situ.

hornbeam and chestnut. Plane-tree may be a ninth genus, but its identification is still uncertain. Conifers are represented in equal quantity by pine and fir. This tree cover is essentially mesothermophilic, indicative of temperate conditions. Perhaps only near the local summits, cool and humid conditions were favorable to beech and fir. The presence of alder and birch is not surprising close to the maar lake, where one would also have found *Filipendula*, Cyperaceae and Typhaceae. Open spaces would have also been found near the lake, as demonstrated by pollen of Poaceae, Apiaceae, sorrel and plantain. Qualitatively, the pollen recovered from the coprolites is essentially comparable to that from the surrounding sediments. The two sets of results are complementary and mutually supportive, pointing to the value of a more systematic search for pollen in the most likely horizons.

d – Preliminary interpretations

The Senèze maar was formed by a phreatomagmatic explosion which released the Laniers basanite flow around 2.4–2.3 Ma. The central basin filled with sediment which records the end of the Réunion normal subchron at 2.1 Ma; at the same time, sediments were being deposited as slope wash on the upper inner face of the crater. The offset of some 50 m in altitude between the penecontemporaneous tephra layers on the slope and in the basin center may be a result of faulting, deposition along a steeply sloping surface or possibly miscorrelation of the tephra layers (which are not mineralogically identical).

Of the mammalian remains recovered by our team, three represent nearly complete individuals of large-bodied taxa found mainly in anatomical association. On preliminary inspection, they preserve little if any evidence of carnivore ravaging, neither punctures nor scratches. Micromammals are rare, with few specimens recovered from sediment screening. The fumarole hypothesis proposed by Couthures (1989) is one possible explanation for this assemblage, but evidence is lacking. An alternative idea envisions mud or debris slides down the inner slopes from the local summits (possibly related to local faulting evidenced in the trench sequences) which engulfed large animals either while still alive or soon after death. The resulting cadavers could have been washed into the lake margin before they could be preyed upon by any of the local carnivores and would have remained in anatomical connection at least during the early phases of preservation. This hypothesis is preliminary at best and requires testing and refinement, which is planned for the 2006 field season, probably our last for this cycle of research.

Summary

The Senèze locality has yielded thousands of mammalian fossils including holotypes of a dozen valid taxa. It is widely accepted as the reference locality for the Late (but not Final) Villafranchian interval (MNQ unit 18), with an age estimated between 2.2–1.5 Ma. Yet because the bulk of the fauna was collected early in the last century by amateurs (especially P. Philis, a local farmer), there has been no data on the stratigraphic position of these fossils, especially by comparison to the deep cores drilled in the center of the maar lake, nor on the taphonomy, and little is known of the micromammals or paleoenvironment. In order to address these questions and place the Senèze fauna on a firmer footing, our team has undertaken renewed fieldwork since 2000. Preliminary results are available for several of our research goals:

1) a basic local stratigraphy (with sedimentology) has been established, revealing a series of layers partly traceable across the basin; this may be facilitated by tephrochronology; some fossiliferous horizons have been recognized; a taphonomic hypothesis has been proposed involving mudflows carrying animals or carcasses into the maar before they could be disarticulated by carnivores.
2) argon dating has resulted in a preliminary confirming date of ca. 2.35 Ma for the Laniers basanite flow which preceded maar formation and a preliminary date of ca. 2.1 Ma for a tephra layer underlying a fault which predates one major fossil find; paleomagnetic profiles suggest that most of the slope deposits are reversely magnetized with one or perhaps two adjacent normal magnetozones; ESR analysis of tooth enamel agrees with an age ca. 2 Ma, but preliminary results must be refined.
3) three well-preserved partial skeletons have been recovered (*Dicerorhinus etruscus etruscus* in 2001, *Eucladoceros ctenoides* in 2004, and *Equus stehlini* in 2005), along with more fragmentary remains of the rare *Acinonyx pardinensis* and a castorid, new to Senèze; palynological analysis indicates a temperate environment with a mix of deciduous and coniferous trees.
4) further systematic paleontological study along with refined dating is required to clearly place Senèze in relative biochronologic and chronometic position by comparison to other European Plio-Pleistocene mammalian assemblages.

Acknowledgements

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DEB–0333415), the National Geographic Society Committee on Research and Exploration (grants 7050–01 and 7434–03), and the L. S. B. Leakey Foundation. We thank TERRY HARRISON and JOHN VAN COUVERING for reviewer comments which improved this report and the volume editors for comments and patience. We also thank proprietors of the land on which we have excarated (especially Monsieur Jean-Jacques CHABRIER and Medames Marguerite LIMAGNE and Marie LONJON), the town of Domeyrat and all the students and colleagues who have worked with us at Senèze.

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