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## The uppermost Oligocene of Aix-en-Provence (Bouches-du-Rhône, Southern France): A Cenozoic brackish subtropical Konservat-Lagerstätte, with fishes, insects and plants

*L'Oligocène supérieur d'Aix-en-Provence (Bouches-du-Rhône) : un Konservat-Lagerstätte cénozoïque subtropical saumâtre à poissons, insectes et plantes*

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### ABSTRACT

Aix-en-Provence is one of the most famous localities for Cenozoic fossils in Europe, known since the end of the 18th century for the exquisitely preserved fishes, insects and plant remains extracted from laminated deposits exposed in the underground quarries developed for the exploitation of the gypsum, and in some sites located inside and around the city. The Aix-en-Provence fossil assemblage includes a considerable variety of organisms that provide a well-documented evidence of the existence of a large subtropical brackish (primarily oligohaline) lagoon temporarily connected to the sea in southern France during the latest Oligocene.

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## R É S U M É

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Aix-en-Provence est, parmi les localités fossilifères les plus remarquables du Cénozoïque européen, connu depuis la fin du XVIII<sup>e</sup> siècle pour ses poissons, insectes and plantes extraordinairement bien préservés, qui ont été extraits des dépôts laminés présents dans les carrières de gypse souterraines, mais aussi de quelques sites de surface dans et autour de la ville. Cette association de fossiles d'Aix-en-Provence contient une diversité considérable d'organismes, qui apporte de très forts arguments en faveur de l'existence d'un vaste lagon d'eau saumâtre (initialement oligohalin) temporairement connecté à la mer dans le Sud de la France à la fin de l'Oligocène.

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## 1. Foreword

In France, Aix-en-Provence is the most famous locality for Cenozoic fossil fishes and one of the most famous for Oligocene fossil insects, mainly because of the extensive exploitation of the gypsum underground quarries called “Les Plâtrières”, where fossils were collected during the 19th century in laminated deposits currently referred to the Aix-en-Provence Formation. Unfortunately, these artisanal quarries are not accessible, the last one having been closed before the Second World War and blasted during the fifties of the last century. For this reason, most of the information related to quarrying activity and collection of fossils can be solely derived from the old descriptions published by several travellers interested in natural history.

In the last decades, however, new productive sites were discovered and explored inside and around the city of Aix-en-Provence, resulting in the discovery of a large amount of fossils that broadly contribute to increase our knowledge of the overall palaeobiodiversity of this Oligocene locality, as well as of its general palaeoenvironmental context and stratigraphic evolution.

## 2. The subterranean “Plâtrières” of Aix-en-Provence

The earliest description of the “Plâtrières” was provided by Michel Darluc (1717–1783) in his *Histoire naturelle de la Provence* (1782). He visited the main quarry exploited at that time, called Jean’s quarry, and observed the occurrence of small fossil fishes characterized by a red coloration and showing a broad head, a pointed snout and a diamond-shaped body. He compared them to small-sized sea breams, or alternatively, probably because of their red colour, to “malarmats”, which are commonly called by “armoured searobins” (*Peristedion cataphractum*). Moreover, he also hypothesized that some other fishes possibly represented grey mullets and sea perch.

Five years later, in 1787, Horace-Bénédict de Saussure (1740–1799) visited the Louis’s quarry, in which he distinguished seven strata, and noted the presence of fossil fishes in the stratum called “pierre schisteuse”. He hypothesized that the deposits of these quarries originated at the bottom of large lakes filled either with fresh water or with salt water, as testified by the co-occurrence of both freshwater and marines fishes (Saussure, 1796).

In September 1805, Barthélemy Faujas de Saint-Fond (1741–1819) visited the Antoine Féraudi’s quarry and provided a detailed stratigraphic description, in recognizing 17 strata of different thickness and lithology (Faujas de Saint-Fond, 1806). He reported the occurrence of fossil fishes in two separate levels, the lower of which is represented by a relatively thick stratum (his stratum 7) located about two to three meters above the upper gypsum and including several fish species with an overall length ranging from about 15 cm to one meter. The second productive level, which is located immediately below the second gypsum, contained abundant fishes of small size (his stratum 17).

However, the most comprehensive description of the gypsum quarries was provided by Charles Bertrand-Geslin (1796–1863), who in 1823 documented and figured the sections of two quarries, one of which comprised at least 26 strata and located near the road to Avignon, and the second one located in the nearby of Éguilles (Bertrand-Geslin, 1823, pl. XVIII). The tunnels of these two quarries are still present and their entrances visible.

Finally, in 1828, during their trip to northern Italy, Roderick Impey Murchison (1792–1871) and Charles Lyell (1797–1875) visited a quarry in which they distinguished 16 strata above the upper gypsum (Murchison & Lyell, 1829). Among the others, they observed the “Feuille à poisons”, the “Feuille à mouches, or Insect bed”, a “very thinly laminated” marl in which they were able to count “more than seventy distinct laminae in the thickness of an inch”. However, it should be noted that their description was strongly inspired by that of Charles Bertrand-Geslin as their stratigraphic succession is almost identical to that provided by Bertrand-Geslin (1823) for the interval comprised between the strata 15 to 26.

## 3. The geology and the age of the Aix-en-Provence Formation

The Aix-en-Provence basin is one of the numerous irregular semi-grabens that originated during the Oligocene in southern France in response to the extensional tectonics that affected the European platform, leading to the formation of West-European rift system and the Liguro-Provençal basin (see Hippolyte et al., 1991, 1993). These Oligocene extensional basins were primarily characterized by shallow water continental sedimentation (Nury, 1988),

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