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II. HISTORIQUE

THE HISTORICAL TYPE HAUTERIVIAN OF THE JURA MOUNTAINS: ORIGINAL DEFINITION, ACTUAL CONCEPT, LITHOSTRATOGRAPHIC SUBDIVISION

by

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RÉSUMÉ. — Selon la définition originale par RENEVIER (1874) l'étage Hauterivien comprend (de haut en bas): Pierre jaune de Neuchâtel, Marne d'Hauterive et Marne à Astieria. La clarté de cette définition n'est qu'apparente: en pratique, il est très difficile de fixer une limite entre Pierre jaune et «Urgonien jaune» d'autant plus que les Marnes de la Russille de la localité-type se situent plus haut dans la série et ne correspondent pas aux «Marnes de la Russille» auct. qui devraient séparer la Pierre jaune de l'«Urgonien jaune». Les ammonites font défaut dans les faciès néritiques de la Pierre jaune et de l'«Urgonien» ce qui empêche les corrélations à longue distance. Ainsi, l'attribution classique de tout l'«Urgonien» jurassien au Barrémien n'est appuyée par aucun argument biostratigraphique. Seule la limite Valanginien-Hauterivien peut être caractérisée par des ammonites; l'ironie veut que cette limite ait été changée par BAUMBERGER (1901) pour placer la Marne à Astieria dans le Valanginien.
Des stratotypes pour le Valanginien et l'Hauterivien furent proposés par HAEFELI et al. (1965). En ce qui concerne l'Hauterivien, ces auteurs ne respectent pas la définition de la limite inférieure de l'étage donnée par RENEVIER (1874) et ne traitent pas le problème de la limite Hauterivien-Barrémien.
Le but des recherches réunies dans ce volume n'était pas de définir un nouveau stratotype de l'Hauterivien dans la région-type historique. Il s'agissait de réunir un maximum d'informations biostratigraphiques pouvant servir de base pour une (re)définition plus précise de l'Hauterivien dans un faciès plus favorable.

ABSTRACT. — The original definition of the Hauterivian stage by RENEVIER (1874) was based on lithostratigraphic units occuring around Neuchâtel (Switzerland) including—from above—Pierre jaune de Neuchâtel, Marne bleue d'Hauterive, and the decimetric Marnes à Astieria. The lower boundary, between Marnes à Astieria and Calcaire roux is clear cut, due to condensation and a hiatus, whereas the passage from Pierre jaune upwards into the so called "Urgonien jaune" is gradual. Ammonites are practically limited to the lower, marly part of the type Hauterivian. The stage was redefined in terms of ammonite zones of SE France by KILIAN (1889, 1895). By this procedure, the condensed Astieria marls became Late Valanginian, a usage followed since BAUMBERGER (1901). The attribution of the "Urgonien jaune" to the Barremian was never justified biostratigraphically (and turned now out to be wrong).

1. THE ORIGINAL CONCEPT

1.1. Original definition of the Hauterivian stage by RENEVIER (1874)

The Hauterivian stage was introduced by RENEVIER (1874) in order to reestablish the Neocomian of THURMANN (1836) in its original meaning. It is beyond the scope of the present lines to enter into the confusing history of the Neocomian, but we should be aware of the two main aspects of the question.
1) The problem of the contents of the original Neocomian in its large sense, often considered at that time as a group of stages,
2) the contradictions arising from the parallel use of a Neocomian s. str., named either Middle Neocomian (CAMPICHE & DE TRIBOLET, 1858, MARCOU, 1858) or Neocomian stage (DESOR & GRESSLY, 1859, JACCARD, 1869) forming, together with the Valanginian and Urgonian stages the Neocomian s. l.
Concerning the first point, RENEVIER (1874) rather added to the general confusion in including the Aptian in his "Infra-Crétacé ou Néocomien". As to the second point, it was certainly a good idea to give a new name, "Hauterivien", to the critical interval of the Middle Neocomian or Neocomian s. str. in order to avoid further use of two Neocomians of different scope. Many problems would indeed have been resolved, had the new stage been properly defined.
Undoubtedly, RENEVIER's (1874) definition of the Hauterivian is very clear in terms of local lithostratigraphic names. The new stage was to include, from top to bottom (fig. 2):

- Pierre jaune de Neuchâtel;
- Marne d'Hauterive à Am. radiatus;
- Marne jaune de Morteau à Am. astierianus.

JACCARD (1869) believed that in the Orbe valley (fig. 1) Pierre jaune and lower "Urgonian" (= "Urgonien jaune"!), although quite similar lithologically, could be separated by a marly intercalation which he called Marnes de la Russille. CONRAD & MASSE (this vol.) were, however, able to show that the Marnes de la Russille of the type locality occupy a higher stratigraphic position. The "Marnes de la Russille" auct. between Pierre jaune and "Urgonien jaune" correspond to another or several other levels. In the region of Neuchâtel these marls are not clearly developped, so that Pierre jaune and "Urgonien jaune" cannot be differentiated cartographically (BAUMBERGER, 1903-1910; BURRI, 1956; MEIA, 1965). The value of Renevier's lithostratigraphic definition thus remains rather theoretical, even though the lower boundary of his Hauterivian, between Marnes à Astieria and Couche de Villers is unambiguous.
In the text of his article, RENEVIER (1874) is more concerned with general philosophy of stratigraphy and no biostratigraphic definition or characteristic of the Hauterivian is given. Some information can, however, be gleaned from the large comparative stratigraphic table (which was not attached to reprints).
Among characteristic Hauterivian invertebrates, the following ammonites are cited: *Ammonites radiatus*, *Am. leopoldinus*, *Am. asterianus*, and *Am. cryptoceras* for "ordinary marine environments", and *Ammonites rouyanus*, *Am. tethys*, *Am. subfimbriatus*, *Am. ligatus*, *Am. angulicostatus*, *Ancyloceras duvali*, *A. tabarelli*, *Hamulina hamus*, and *Ptychoceras emerici* for the alpine realm.
It is also rather significant that in RENEVIER's (1874) table the Hauterivian is followed by an Urgonian stage and that the Barremian of COQUAND (1862) is indicated as a possible synonym of the Hauterivian.

1.2. Facies and depositional environment of the historical type Hauterivian

Another drawback of Renevier's Hauterivian is that it was defined in rather neritic facies where ammonites are missing in most of the succession.
The Hauterivian (in its original lithostratigraphic sense) is preceded by the Valanginian Calcaire roux, a current-bedded, ferrugineous grainstone (fig. 2), deposited in a shallow environment with high water energy. Near the top, beds begin to dissociate into irregular nodules, embedded in a yellow, marly-sandy matrix which becomes more and more important upwards. The Calcaire roux thus passes rapidly into a condensed

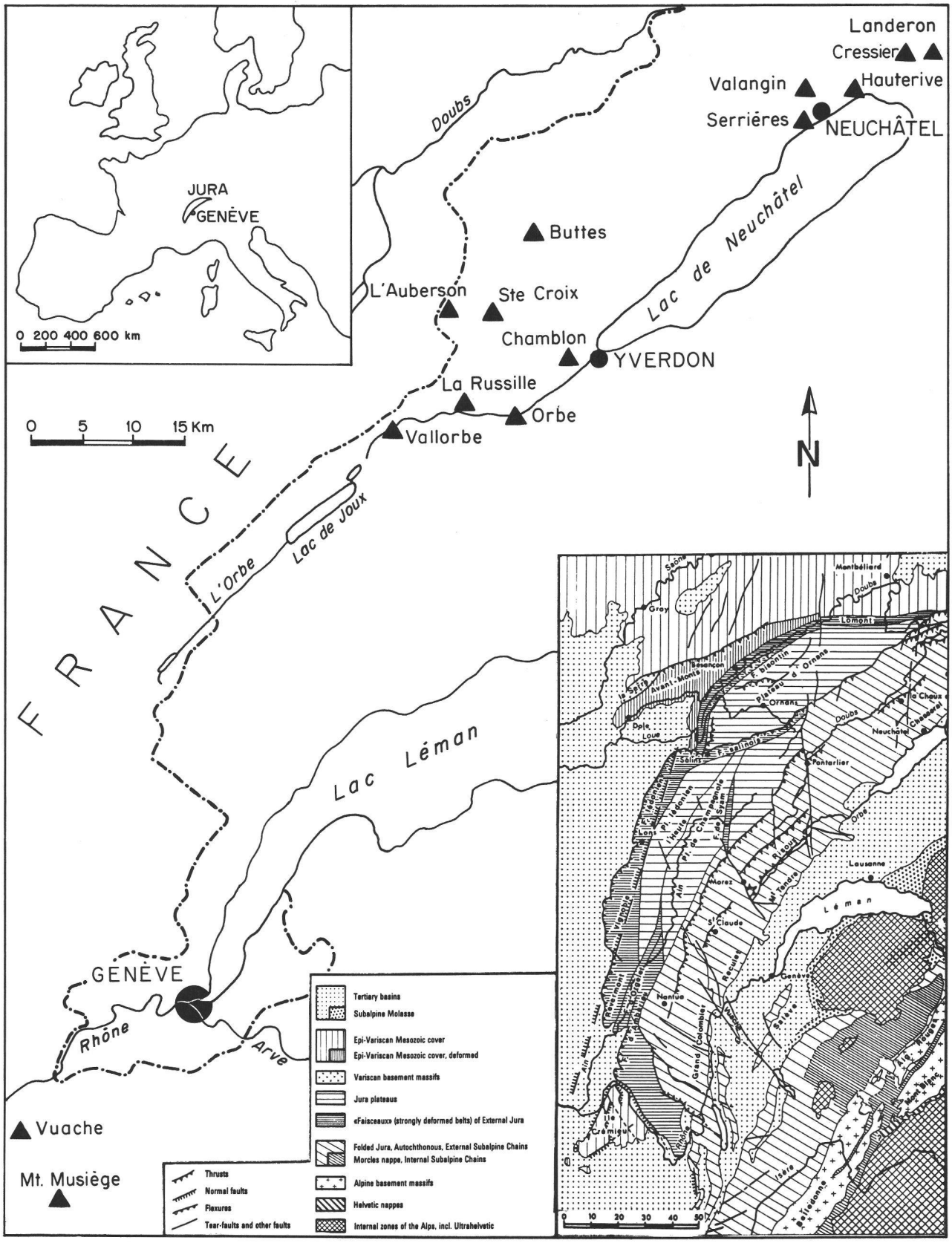

FIG. 1. — Map of the central Jura Mountains, showing the geographic locations of sections studied by REMANE et al. (this vol.) and by Charollais et al. (this vol.). From these sections, all the materials dealt with in the biostratigraphic contributions of this volume have been collected.

layer, only some tens of centimetres thick. This is the Couche de Villers where two *Saynoceras verrucosum* have been found at Valangin, indicating an early Late Valanginian age in terms of current usage. But there are also reworked Early Valanginian ammonites (BUSNARDO & THIEULOY, this vol.).
The Couche de Villers is overlain by 20-30 cm of yellow, clayey marls, the "Marne jaune de Morteau à *Ammonites astierianus*" (syn.: Marne(s) à Astieria, Astieriamergel, Astieriaschicht). This is another condensed bed, rich in ammonites (especially olcostephanids) at several localities. The Marnes à Astieria are limited to a relatively small area around and W of Neuchâtel (BAUMBERGER, 1901: 45), but some sort of condensation is always observable in the Valanginian-Hauterivian passage beds, whatever their lithology may be. Earlier authors tried to correlate the various residual sediments of different localities, but of course without success.

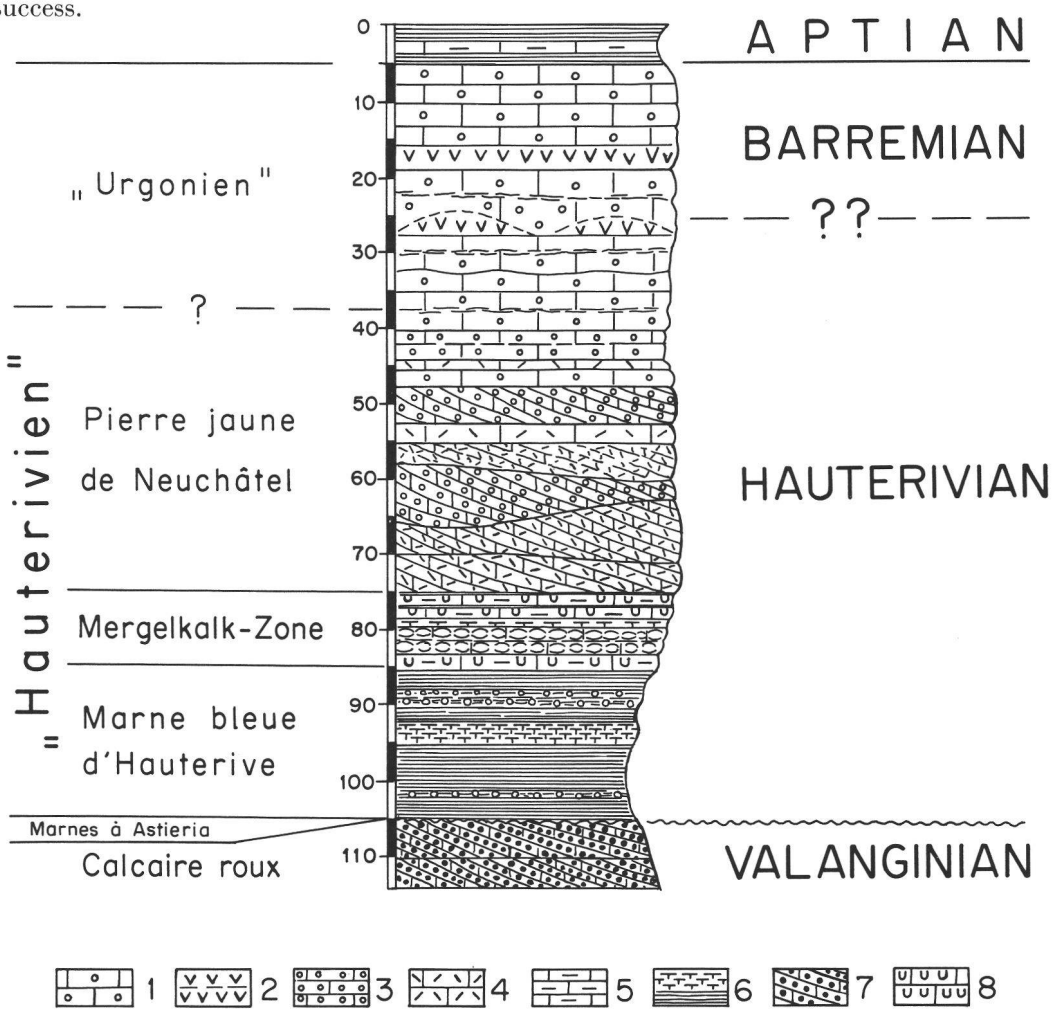

FIG. 2. — Schematic profile showing the lithostratigraphic context of the historical type Hauterivian near Neuchâtel; at left: local lithostratigraphic units, at right: ages. 1) pelsparites; 2) coral limestones (bioherms or biostromes); 3) oosparites; 4) biosparites; 5) marly limestones; 6) calcareous marls and marls; 7) ferrugeneous oolites; 8) burrows.

Normal sedimentation starts again with the overlying Marne(s) bleue(s) d'Hauterive (syn.: Marne bleue, Marne d'Hauterive). This is an open marine stillwater sediment, up to 20 m thick in the Neuchâtel region. Ammonites are frequent in the lower part, but *Acanthodiscus* and *Leopoldia*, two rather "shallow" genera, predominate clearly. In the upper Marne bleue benthic fossils (bivalves, brachiopods) become more and more abundant. (BAUMBERGER, 1903-1910).

So we pass into the Mergelkalkzone (syn.: Zone des marno-calcaires) built up of yellowish, more or less marly limestones with thin marly intercalations. The limestones vary from wackestones to grainstones with current bedding, but intensely bioturbated packstones and, above all, grainstones predominate. If is often difficult to fix a boundary between the Mergelkalkzone and the overlying Pierre jaune (de Neuchâtel) which is dominated by current-bedded oo- and biosparites with some glauconite and many echinoderm and bryozoan fragments. Marly intercalations are rare and inconspicuous in the Neuchâtel region and only one of them attains a thickness of 80 cm (KIRÀLY 1964).
Seen as a whole, the sedimentary environment must have been very similar to that of the Calcaire roux. Measuring systematically sedimentary structures of the Pierre jaune, KIRÀLY (1965) was able to show that current directions remained rather constant, oscillating between 125 ° and 160 °. But obviously no valuable biostratigraphic information can be obtained from grainstomes of this kind.
The regression continues with the so-called "Urgonien" of the Jura Mountains. There are still grainstones, but without current bedding. The most characteristic feature is the appearance of biomicrites rich in massive bryozoans, stromatoporoids, sphinctozoans, and reef-building corals. Orbitolinids and dasyclad algae are frequent at certain levels. All these sediments were undoubtedly deposited on a shallow carbonate platform.

1.3. **Problems arising from Renevier's definition**

The above-mentioned facts allow a critical appreciation of RENEVIER's (1874) definition of the Hauterivian stage.
First of all, RENEVIER's biostratigraphic indications are too vague to give a clear idea of the scope of the Hauterivian stage, and the clarity of the lithostratigraphic definition is only apparent. The upper boundary of the Hauterivian is undefinable in the historical type region. Only the lower boundary can be fixed precisely in the successions around Neuchâtel and ironically it was just this boundary that was changed by BAUMBERGER (1901).
The facies of the historical type Hauterivian are not favourable for long distance correlation. Only the Valanginian-Hauterivian boundary can be characterized by ammonites, but two restrictions have to be made:
1) The special character of the ammonite faunas of the Marne bleue,
2) the highly condensed Upper Valanginian which contains, moreover, reworked Early Valanginian species, as *Platylenticeras gevrillei* (BUSNARDO & THIEULOY, this vol.)

So it is not surprising that later workers who tried do define the Hauterivian stage in term of ammonite zones (at first KILIAN, 1889, 1895) turned to the pelagic facies of the Vocontian Trough in SE France.

2. **FURTHER EVOLUTION OF THE HAUTERIVIAN IN ITS HISTORICAL TYPE REGION**

2.1. **Modification of the Valanginian-Hauterivian boundary by BAUMBERGER (1901)**

The development of the Hauterivian ammonite zones will be dealt with in another chapter (BUSNARDO & THIEULOY, this vol.). Here it is only important to retain that KILIAN (1895) adopted a Valanginian-Hauterivian boundary corresponding to the base of the *Acanthodiscus radiatus* Zone, thus including the fauna of the Marnes à Astieria in the Valanginian. Whatever the reason of this change may have been, it is evident that Kilian simply did not care about priority of definition, as he wrote (KILIAN, 1895: 746), with respect to the Pierre jaune: "(M. RENEVIER range cette assise dans l'Hauterivien, et il nous semble qu'il n'a a pas lieu d'y attacher trop d'importance)" — parantheses in Kilian's text! Kilian thought the Pierre jaune to be of Barremian age, which is definitely wrong, according to his own definition of the Hauterivian.
In their description of the Valangin section, BAUMBERGER & MOULIN (1899) placed the Marnes à Astieria still in the Hauterivian. But BAUMBERGER (1901) changed his mind and now they became Valanginian, because of the "Valanginian character" of their ammonite fauna. Schardt did never accept the new Valanginian-Hauterivian boundary (e. g. SCHARDT, 1908a), but most other stratigraphers have followed BAUMBERGER.

Again one is surprised that priority of definition was never taken into consideration, not even by SCHARDT who could have used it as a strong argument in favour of his views. Although priority is not obligatory in stratigraphy, it seems obvious that a boundary should only be changed if this results in improved long distance correlation. This point was never mentioned and instead we are left with rather nebulous arguments as the "Valanginian" or "Hauterivian" character of different parts of the fauna of the Marnes à Astieria.

2.2. **The Hauterivian-Barremian boundary**

In a first time, the Barremian stage of COQUAND (1862) was thought to be missing in the Jura Mountains (DESOR, 1864). Most authors of the last century continued to use the Urgonian of D'ORBIGNY (1847) as stage name for the strata overlying the Pierre jaune. The Barremian was only introduced by BAUMBERGER (1901). since then, the term "Barrémien" has replaced the "Urgonien" as a stage name, but stratigraphic boundaries were not changed and there were no biostratigraphic arguments for a Barremian age of Urgonian facies of the Jura Mountains. The distinction between "Hauterivian" and "Barremian" was thus inevitably a purely lithological one, BAUMBERGER (1903-1910) himself stated that no paleontological difference could be observed. Under these conditions the only possibility to draw a boundary between the two "stages" was to find a marly intercalation which could be taken for the equivalent of the "Marnes de la Russille", as did FREI (1925) at Serrières. But there are several nodular levels with a marly matrix in the passage beds between Pierre jaune and "Urgonien jaune" and as shown quite recently by CONRAD & MASSE (this vol.) none of them corresponds to the Marnes de la Russille of the type locality.
BURRI (1956) was the first to arrive at a biostratigraphic distinction between "Hauterivien" and "Barrémien" on the base of rhynchonellids. But we should be aware of the fact that "Barrémien" means in reality Urgonian facies of the Jura Mountains. And there are now rather strong arguments that the lower "Urgonian" is of Hauterivian age according to Kilian's definition by ammonites (MASSE et al., this vol.).

2.3. **Hauterivian stratotypes proposed by HAEFELI et al. (1965)**

In a recent revision of the Valanginian and Hauterivian stages in the historical type region (HAEFELI, MAYNC, OERTLI & RUTSCH, 1965), several sections were measured in detail by HAEFELI, foraminifera studied by MAYNC and ostracods by OERTLI. On this base, RUTSCH proposed stratotypes for the Valanginian and the Hauterivian stages.
The Hauterivian is combined from the following profiles:

1) Valangin, showing the transition from the Calcaire roux up into the lowermost Marne bleue and then the uppermost Marne bleue and the lower part of the Mergelkalkzone,
2) Hauterive (in reality at Neuchâtel): upper Marne bleue and lower Mergelkalkzone,
3) Le Landeron, a profile combined from three outcrops covering the interval from the uppermost Marne bleue up into the Pierre jaune. None of these stratotype sections shows the transition from the Pierre jaune to the "Urgonien".

The sections of Valangin and Neuchâtel (= "Hauterive") are still open to the same degree as at HAEFELI' time, but the whole complex of Le Landeron is rather problematic. The quarry in the Pierre jaune is being filled up with rubble, the lowermost section is tectonically disturbed and the middle part, again a quarry, is no longer accessible. A villa has been built there and a nice garden arrangement showing Little Snow White and the seven dwarfs occupies the place where, once upon a time, the Mergelkalkzone was to be seen.
The base of the Valanginian and of the Hauterivian stage are formally defined (in reality redefined) by RUTSCH (in HAEFELI et al., 1965: 44). The Valanginian-Hauterivian boundary is thus fixed at the top of the Marnes à Astieria at Valangin. The redefinition of the Hauterivian-Barremian boundary is postponed until a suitable type-section will be available in the Neuchâtel region.
RUTSCH is aware of the fact that the top of the Hauterivian as defined by RENEVIER (1874) will certainly not coincide with the base of the Barremian at Angles. Therefore his proposal (in HAEFELI et al., 1965: 47) to

attribute a Hauterivian age only to strata belonging to the time interval between Marnes à Astieria and Marne de la Russille. But this does not raise the contradiction between two definitions of the same boundary. It also remains mysterious, why priority is given to RENEVIER's definition, since the Barremian was introduced 12 years earlier by COQUAND (1862). In the same time, RENEVIER's definition of the Valanginian-Hauterivian boundary is abandoned for faunal reasons! Following RUTSCH's own logic, the Marnes à Astieria would have to be considered as Hauterivian "ex definitione". Finally, the problem that the correlation potential of rigid unit-stratotypes of this kind might be insufficient, is not even taken into consideration. But this is indeed the crucial point, for what could be the use of a definition which cannot be applied in practice?

3. AIM OF THE PRESENT STUDY

The study of ostracod and foraminiferal biostratigraphy carried out by OERTLI and MAYNC in the context of the work of HAEFELI et al. (1965) was an important step towards a better understanding of the historical type Hauterivian (and Valanginian). Nannoflores of two of HAEFELI's localities (Valangin and Neuchâtel = "Hauterive") were studied by THIERSTEIN (1973).
But ammonites have not been reviewed since the monograph of BAUMBERGER (1903-1910) and for the rest of the macrofauna we have to go even further back. For this reason it seemed interesting to take up the whole problem again on a broader biostratigraphic base, including the fossil groups mentioned above (see Avant-Propos). On a broader base also in extending the revision into the Urgonian facies and finally also on a broader scale regionally speaking, including the region of Sainte-Croix and Mont-de-Chamblon (Canton de Vaud) and the southern Jura Mountains of Haute-Savoie (France) in the vicinity of Geneva.
The aim of our research project was not, however, to institute (or reinstitute) a stratotype of the Hauterivian stage in a facies known to be unfavourable for long-distance correlations, especially in the Upper Hauterivian which is not documented by ammonites. But also a limitotype for the lower boundary of the Hauterivian would only be of limited value due to the condensation having affected the "Couche de Villers" and "Marnes à Astieria". But it seems important that a maximum of biostratigraphic information on the historical type region is gathered, before a redefinition of the Hauterivian stage in an ammonite facies is envisaged.

4. POSSIBILITIES FOR A LITHOSTRATIGRAPHIC SUBDIVISION OF THE HAUTERIVIAN IN THE CENTRAL SWISS JURA MOUNTAINS

4.1. Earlier work on Hauterivian stratigraphy

Since the first geological monograph of the Canton de Neuchâtel by DESOR & GRESSLY (1859) other valuable contributions to Hauterivian stratigraphy have been made by various authors. First of all the "Description géologique du Jura vaudois et neuchâtelois" of JACCARD (1869) and the outstanding work on lower Cretaceous stratigraphy and ammonite faunas of BAUMBERGER (1903-1910), which was preceded by a general overlook over facies and paleogeography (BAUMBERGER, 1901) should be remembered. In these publications the foundations of regional Hauterivian stratigraphy were laid, including the definition of current lithostratigraphic units.
More recently, BURRI (1956), in his revision of Valanginian to Barremian rhynchonellids, has presented an excellent review of problems concerning lower Cretaceous stratigraphy of the Swiss Jura Mountains. The Cretaceous of the French Jura Mountains was studied recently by GUILLAUME (1966).
As far as the central Swiss Jura is concerned, our study concentrated on the region around Neuchâtel / Hauterive, on the environments of Sainte-Croix, and on Mont-de-Chamblon (fig. 1) for the classical Hauterivian. Additionally, "Urgonian" sections were measured in the Orbe valley, at Vallorbe, near Buttes and some localities of the French Jura (see MASSE et al., this vol.).

In our context, the work of KIRÀLY (1964, 1965) on the Pierre jaune around Neuchâtel and three regionally oriented theses are also very important: RITTENER (1902), FREI (1925), and JORDI (1955). The region between Neuchâtel and Mont-de-Chamblon, not studied in detail by us, is covered by BERTSCHY (1958) and MEIA (1965, 1969). Important publications of more local interest will be discussed when dealing with individual profiles (REMANE et al., this vol.).
The above mentioned publications contain a wealth of stratigraphic information and although formations, members and so on have never been formally defined, a certain number of lithostratigraphic units have emerged which are still in general use. The most important of them have already been characterized briefly above. But, before entering into a biostratigraphic revision, the real value of these current lithostratigraphic units had to be tested, i. e. the lithostratigraphic nomenclature to be used in this publication had to be clarified. The meaning was not, however, to introduce a formal hierarchy with groups and formations because this would have made necessary a thourough revision of regional geology which was beyond the scope of a stage revision.
The main accent of lithostratigraphic descriptions (REMANE et al., this vol.) is placed on criteria permitting to recognize again characteristic levels which may serve as a starting point for those who want to restudy our profiles. In the same sense, the critical appreciation of the reliability of field data are given a large space. Sections in the classical Hauterivian of the central Swiss Jura Mountains were measured and sampled by J. REMANE with the help of assistants and students mentioned in the Avant-Propos. Macrofaunas were collected together with R. BUSNARDO, J. CHAROLLAIS, B. CLAVEL, and J.-P. THIEULOY and lithostratigraphy was elaborated in common during these field trips.

4.2. **Current lithostratigraphic subdivision of the historical type Hauterivian**

In the region around Neuchâtel (and Hauterive), the Hauterivian sensu BAUMBERGER (1901, 1903-1910) is currently subdivided into three informal lithostratigraphic units:

(Urgonien jaune)	"Barrémien"
Pierre jaune (de Neuchâtel) Mergelkalkzone Marne bleue (d'Hauterive)	"Hauterivien"
(Marnes à Astieria)	Valanginian

The facies corresponding to these units have already been described above. Most regional stratigraphers have adopted this scheme, but disagree where to draw the (lithostratigraphic) boundary between Lower and Upper Hauterivian.
BAUMBERGER & MOULIN (1899) placed the Mergelkalkzone in the Lower Hauterivian, whereas the Upper Hauterivian was represented by the Pierre jaune only. Among recent authors, JORDI (1955) and BERTSCHY (1958) have followed this proposal. SCHARDT (1908 a, b) and FREI (1925) attributed the Mergelkalkzone to the Upper Hauterivian which is much more logical from the lithostratigraphic standpoint. Baumberger was probably guided by biostratigraphic considerations and under this aspect, the Lower Hauterivian has indeed to be extended higher up. As will be shown (BUSNARDO & THIEULOY, this vol.) the entire Marne bleue belongs to the Radiatus and Loryi Zones and even a part of the Pierre jaune is still of Early Hauterivian age. BURRI (1956) has given other examples of a contradictory use of the terms Lower and Upper Hauterivian in the Swiss Jura. If we take into consideration that since BAUMBERGER (1901) everybody agrees that both boundaries are diachronous. it seems only logical to abandon altogether "Lower" and "Upper" Hauterivian for the region under study. It is, by the way, interesting to note that BAUMBERGER made already a first step in this direction. In 1901 he used four lithostratigraphic divisions without classifying them in Lower and Upper Hauterivian. Five years later, howewer, he distinguished (BAUMBERGER 1903-1910) two main units

named Kalkfazies = Pierre jaune and Mergelfazies (including also the famous Mergelkalkzone). Cautiously, the terms Lower and Upper Hauterivian reappear one or two pages below, and the problem is there again. With respect to finer subdivisions than the basic threefold scheme presented above, DESOR & GRESSLY (1859) had already recognized that further lithostratigraphic subdivisions of the Pierre jaune were only of local interest. No attemps towards a generalized subdivision of the Pierre jaune have been made since. The subdivision of the "Marnes néocomiennes" (= Marne bleue) into (from top to bottom): 1° marnes blanchâtres à concrétions calcaires, 2° marnes bleues homogènes, 3° marnes jaunes (DESOR & GRESSLY, 1859: 34) was however believed to be valid for the whole region. This subdivision has survived (HAEFELI et al., 1965) although it does not quite correspond to reality. At Cressier as well as at Le Landeron calcareous nodules are present in the lower Marne bleue and all what can be said is that at certain levels of upper Marne bleue nodules attain higher concentrations than in the lower part. In other words, a more than purely local lithostratigraphic subdivision of the classical Hauterivian around Neuchâtel is limited to the three basic units Pierre jaune, Mergelkalkzone, and Marne bleue. The next question is then, how far this scheme can be extended regionally.

4.3. **Lateral extent of the lithostratigraphic units observed in the Neuchâtel/Hauterive region**

The basic threefold subdivision of the classical (i.e. lithostratigraphic) Hauterivian applies of course best to Neuchâtel itself and to the innermost, southeastern chain of the Jura Mountains NE of Neuchâtel (Cressier, Le Landeron). The succession of Valangin fits also in this scheme, altough the thickness of the Marne bleue is reduced from nearly 20 m to 7 m. Following the foot of the Jura Mountains to the SW, the three main terms of the succession can still be identified, but some additional elements show up. According to BERTSCHY (1958) intercalations of lumachellic limestone appear in the upper Marne bleue between Neuchâtel and Yverdon. Similarly, JORDI (1955) observed a group of three beds of bioclastic glauconitic limestones 10-12 m below the Mergelkalkzone at Mont-de-Chamblon.
On the other hand, about 3 m of yellow marls are intercalated in the upper Pierre jaune at Mont-de-Chamblon. These "Marnes à Eudesia semistriata" (SCHARDT, 1900) have been renamed "Marnes d'Uttins" by JORDI (1955).
The succession in the Ravin du Colas (= Colaz = Collaz) near Sainte-Croix is the one which differs most from the above mentioned three-fold subdivision. As a matter of fact, typical Pierre jaune lies directly on typical Marne bleue, and no Mergelkalkzone can be distinguished. A marly intercalation appears in the lower Pierre jaune, and two hard, more or less bioclastic marly limestones are intercalated in the Marne bleue (RITTENER, 1902). The position of the Valanginian-Hauterivian boundary in the Colas section was always controversial (SCHARDT, 1895, 1899b, RITTENER, 1902, BAUMBERGER 1903-1910). New finds of ammonites and echinids have shown that the lowermost Marne bleue is of Valanginian age (BUSNARDO & THIEULOY, CLAVEL, this vol.).

5. **BIBLIOGRAPHY**

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