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THE MIDDLE-UPPER QUATERNARY OF THE "ASTI BASIN"

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ABSTRACT - *The middle-upper quaternary of the "Asti basin"* - Il Quaternario, **4**(1a), 1991, p. 151-172 - A description is given of fluvial deposits and shapes recognized and mapped for the first time at various altitudes in the hilly area between the River Tanaro and the Po watershed to the North, the course of the Borbore stream to the South, the escarpment that marks the eastern edge of the Poirino Tableland to the West, and a meridian line striking close to the city of Asti to the East. In view of their planimetric and altimetric distribution, and their varying degree of preservation and pedogenetic evolution, the fluvial deposits have been divided into two litho-pedo-morphostratigraphic complexes (A and B). Complex B is further divided into Unit A and Unit B. It has proved possible to relate the entire series to the Lower Middle-Upper Pleistocene using a local pedostratigraphic scale devised according to Arduino *et al.* (1984), and appropriately calibrated with chronostratigraphic data derived from neighbouring areas.

The fluvial nature of these deposits is revealed both by their distribution, which displays spatial continuity with those forming the Poirino Tableland surface immediately to the West, and by the presence of an rare and sporadically distributed coarse fraction (pebbles with a maximum diameter of 2÷3 cm), whose lithology (green stones with subordinate gneisses and quartzites) is clearly distinct from the Upper Miocene-Villafranchian local substrate, characterized solely by quartz ± conglomerate pebbles. Further confirmation of this genesis is offered by the erosional nature of the basal surface of these deposits on the substrate, which is only visible locally. Air photos have also revealed variously reworked relic forms (mainly fluvial channels) in association with the deposits. The distribution of these fluvial forms suggests that the main lines of the local stream net were substantially the same as today in its earliest pattern, though its establishment took place under very different morphological conditions. At the beginning of the Middle Pleistocene, in fact, the Asti hills were a mainly flat country, corresponding to an erosional fluvial plain, from which a series of slight, isolated rises protruded. It seems most likely that the ancient net was the eastward continuation of that whose traces have been recognized on the Poirino Tableland by Forno (1980), which drained the South Piedmontese basin and flowed to the South of the Turin and Monferrato hills until it reached the Po plain through what are now the Alessandria flatlands.

The fact that in the Asti reliefs between the Poirino Tableland and the Alessandria flatlands the individual terms of the sequence of the deposits linked to this net are distributed over terraced surfaces, whereas they are superimposed one upon another in the corresponding distribution districts of the two neighbouring area, is an outcome of lifting of the Asti Reliefs during the Middle Pleistocene. The differential nature of the mobility of this sector, with its greater uplifting in the Eastern and Southern sectors as opposed to the elongated, approximately WNW-ESE sector, is brought out by comparison between the present and original (reconstructed) geometrical configuration of their fluvial deposits. Furthermore, the pattern of the longitudinal profiles of the surfaces of the main collector in the time periods considered (area now occupied by the roughly E-W sections of the Borbore and Triversa stream), in which counterslopes are readily visible, suggests that differential lifting also took place along the E-W axis. The present morphological configuration of the Asti Reliefs, whose tops are little higher than the surface that can be thought of as linking the Poirino Tableland with the Alessandria flatlands, is attributed to the insertion of a large tectonic structure (Marginal Flexure of the Poirino Tableland) during the Holocene.

RIASSUNTO - *Il Quaternario medio-superiore del "Bacino di Asti"* - Il Quaternario, **4**(1a), 1991, p.151-172 - Vengono descritti depositi e forme fluviali, riconosciuti e cartografati per la prima volta a quote variabili nell'attuale area collinare compresa tra lo spartiacque tra il F. Tanaro e il Po, a Nord, il corso del T. Borbore, a Sud, la scarpata che segna il margine orientale dell'Altopiano di Poirino, ad Ovest, ed il meridiano che passa immediatamente ad Est della città di Asti, verso Est.

I depositi fluviali, in base alla diversa distribuzione plano-altimetrica, al grado variabile di conservazione e allo stadio pure variabile di evoluzione pedogenetica, sono stati suddivisi in due Complessi lito-pedo-morfostratigrafici, Complesso A e Complesso B, quest'ultimo a sua volta suddiviso nelle Unità B1 e B2. E' stato possibile riferire cronologicamente queste suddivisioni nel loro insieme ad un intervallo di tempo compreso tra la parte inferiore del Pleistocene medio e il Pleistocene superiore, utilizzando una scala pedostratigrafica locale, stabilita con la metodologia proposta in un recente lavoro di Arduino *et al.* (1984), opportunamente calibrata con i dati cronostratigrafici desunti da aree limitrofe.

La natura fluviale dei depositi riconosciuti è indicata, oltre che dalla loro distribuzione, in evidente continuità spaziale con gli analoghi depositi che costituiscono in superficie l'Altopiano di Poirino immediatamente contiguo verso Ovest, dalla presenza di una frazione grossolana, sia pure molto scarsa e distribuita sporadicamente, costituita da ciottoli del diametro massimo di 2÷3 centimetri, la cui natura litologica (pietre verdi e subordinati gneiss e quarziti) si differenzia nettamente da quella, esclusivamente quarzosa e quarzoso-conglomeratica, che localmente caratterizza i ciottoli presenti nelle formazioni del substrato, di età da miocenica superiore a villafranchiana. Un ulteriore elemento a conferma di questa interpretazione genetica è rappresentato dalla natura erosionale della superficie di appoggio dei depositi stessi sul substrato, visibile solo localmente.

Lo studio aereo-fotografico ha consentito inoltre di riconoscere, associate a questi depositi, forme relitte (essenzialmente canali fluviali) caratterizzate da un grado variabile di rimodellamento. La distribuzione di queste forme fluviali ha consentito di ricostruire l'evoluzione del reticolato idrografico locale: questo, nella sua configurazione più antica ricostruibile, non appariva sostanzialmente dissimile, nelle sue direttrici principali, da quello attuale. La sua impostazione era avvenuta però in condizioni morfologiche profondamente diverse dalle attuali: l'area corrispondente agli attuali rilievi collinari dell'Astigiano, all'inizio del Pleistocene medio, presentava infatti una morfologia prevalentemente pianeggiante, corrispondente ad una superficie di accumulo alluvionale, dalla quale sporgevano una serie di modesti rilievi isolati. L'antico reticolato idrografico rappresentava, secondo ogni evidenza, la prosecuzione verso Est di quello le cui tracce sono state riconosciute sull'Altopiano di Poirino (Forno, 1980), il quale raccogliendo il deflusso del bacino piemontese meridionale, defluiva a Sud dei rilievi della Collina di Torino e del Monferrato raggiungendo la Pianura Padana attraverso l'area corrispondente all'attuale pianura Alessandrina. Il fatto che nei Rilievi dell'Astigiano, interposti tra l'Altopiano di Poirino e la Pianura Alessandrina, i singoli termini della sequenza dei depositi legati a questo reticolato idrografico siano distribuiti su superfici terrazzate mentre nei corrispondenti areali di distribuzione delle due aree limitrofe gli stessi appaiono invece giustapposti, viene interpretato come conseguenza del sollevamento che l'area attualmente corrispondente ai Rilievi dell'Astigiano ha subìto durante il Pleistocene medio.

La natura differenziale della mobilità di questo settore, con sollevamento maggiore dei settori settentrionale e meridionale rispetto al settore centrale allungato circa WNW-ESE, viene evidenziato dal confronto tra l'assetto geometrico attuale dei depositi fluviali presenti in quest'area e quello primario, ricostruito. L'andamento dei profili longitudinali delle superfici modellate nei diversi intervalli di tempo considerati dal collettore principale (area attualmente occupata dai tratti diretti circa E-W dei T. Borbore e Triversa), nei quali risultano chiaramente delle "contropendenze", indica inoltre una componente differenziale del sollevamento anche in senso Est-Ovest. L'attuale situazione morfologica dei Rilievi dell'Astigiano, le cui sommità si sviluppano a quote di poco più alte della superficie che virtualmente collegherebbe l'Altopiano di Poirino con la Pianura di Alessandria, viene imputata all'impostazione durante l'Olocene di una importante struttura tettonica (Flessura marginale dell'Altopiano di Poirino).

Key-words: Stratigraphy, Middle Pleistocene, Upper Peistocene, Asti Basin
Parole chiave: Stratigrafia, Pleistocene medio, Pleistocene superiore, bacino di Asti

1. INTRODUCTION

This paper represents the re-elaboration and successive development of the one Author's (Valpreda, 1981) dissertation on the Middle and Upper Quaternary in the area known in the literature as the "Asti Basin". It forms part of a project directed to the reconstruction of the evolution of the Langhe Monferrato districts and the Turin hills, initiated several years ago by the Department of Earth Sciences (University of Turin).

The programme began with the investigations carried out for the preparation of the "Neotectonic Map of Italy" as part of the National Research Council's "Geodynamics Project". It was then pursued within the goals of the "Stratigraphic research on the Quaternary in the Monferrato area" project (Head: F. Carraro) financed by the Ministry of Education.

The results acquired so far (Forno, 1979; 1982; Giraudi, 1981; Valpreda,1981; Alessio *et al.*, 1982; Terzano, 1985) have been incorporated in "The 1:500,000 Neotectonic Map of Italy" (Ambrosetti *et al.*, 1987).

The possible presence in this area of fluvial deposits attributable to a time span running since the end of the Lower Pleistocene(1) has been suggested as a means of verifying Carraro's hypothesis (1976) that the "principal watercourse draining the Southern Piedmontese basin" ran to the South of the Turin Hills and to the Eastern part of the Monferrato, prior to the Upper Pleistocene.

In the course of this research, the opportunity was taken to employ a recently performed investigation method, namely "morphostratigraphy".

"Morphostratigraphy" (Carraro & Ferrarino, 1982) is still in the stage of experimental application and verification. Its aim, in hilly country such as that of the "Asti Basin", is to detect the different "modelling units", so as to determine a geological chronology via the geometric ratios between the erosional forms and the dated deposits.

The series of modelling episodes involved in the evolution of a landscape, in areas where erosion predominates, has been the subject of particular "philosophical"-methodological studies. Of these, reference may be made to the papers by Alessio *et al.* (1982) and Carraro *et al.* (1982), which describe further attempts to apply this method. Subsequently, an organic reformulation of the ideas involved and their application to a large area in Southern Lazio has been carried out in a research project promoted by ENEA (Italian Nuclear and Alternative Energies Research Commission) (Carraro, 1985) and in the studies for a power-plant project in Piedmont (Carraro *et al.*, in press). The method worked out during this research is substantially the same as that used for the study reported here.

In addition, pedostratigraphy was used in accordance with the premises and criteria put forward by Arduino *et al.* (1984).

(1) The chronology here adopted is Richmond's "International paleomagnetic correlation scale" (cf. AIQUA, 1982).

2. PREVIOUS STUDIES

Apart from the fluvial deposits on the valley floors, the only Quaternary deposits marked on earlier maps of the Asti region were the two lower terraces on the left side of the Borbore river between the town of S. Damiano and the city of Asti(2). These sediments have been regarded as fluvial deposits and attributed as a whole to the "Terrazziano" (= Holocene, on the scale adopted here) on the first edition of Sheet 69, "Asti", of the 1:100,000 Geological Map of Italy (Sacco, 1922). In the second edition, these sediments were divided into two terms(3) (called "Middle Fluvial" and "Recent Fluvial", respectively) and ascribed in generic terms to the Pleistocene (Boni & Braga, 1970). Gabert, in his monograph on the Western sector of the Po Plain (1962), sees these terraced surfaces as remnants of a *glacis* whose modelling took place in the "Middle Quaternary". He de

(2) The region includes the Villafranchian type-area. According to the latest views, this comprises the Upper Pliocene as well as the Lower Pleistocene. For the sake of brevity the term "Quaternary" here refers to the post-Villafranchian part of the series only.

(3) Described as "mainly sandy-silty-clayey alluvial with yellowish alteration products" and "gravelly-sandy-silty alluvial and paleosoils with reddish alteration products".

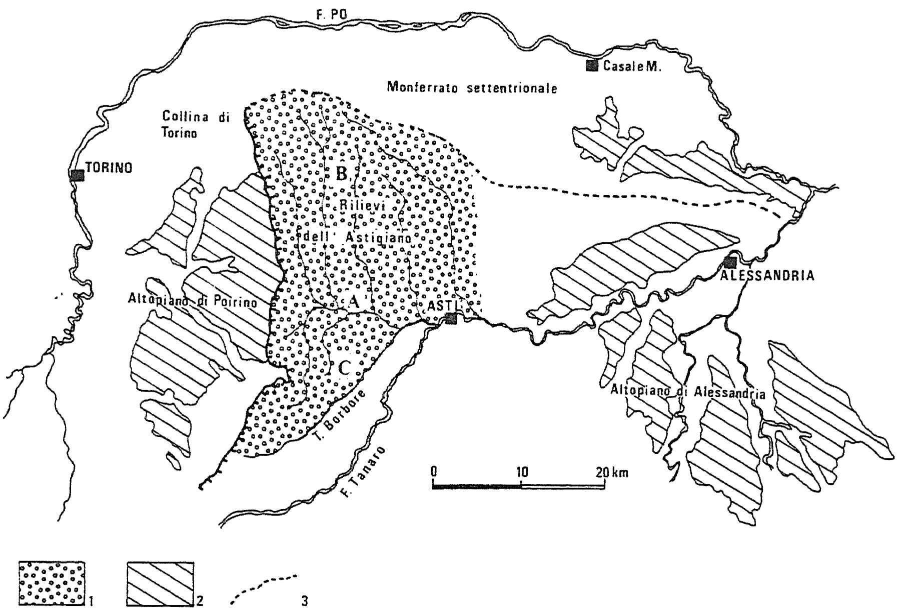


Fig. 1 - The Asti Reliefs are between the Alessandria Plain to the East and the Poirino Tableland to the West. At the surface, these last two morphologic units are made up of fluvial deposits which are comparable in terms of sedimentological characteristics as well as pedologic evolution. The presence of similar deposits in the Asti Reliefs indicates that a paleodrainage crossed the three sectors from West to East: 1) study area; (A) central sector; (B) northern sector; (C) southern sector; 2) Poirino Tableland and Alessandria Plain; 3) present day watershed between the rivers Po and Tanaro.

I Rilievi dell'Astigiano sono compresi tra l'Altopiano di Poirino, verso Ovest e la Pianura di Alessandria, verso Est; queste ultime due unità morfologiche sono entrambe costituite in superficie da depositi fluviali tra loro confrontabili per caratteri sedimentologici e pedologici. La presenza nei Rilievi dell'Astigiano di depositi analoghi ai precedenti per caratteri sedimentologici e per grado di evoluzione pedologica indica l'esistenza di un paleodrenaggio che attraversava i tre settori con direzione di flusso da Ovest verso Est. 1) area oggetto del presente studio: (A) settore centrale; (B) settore settentrionale; (C) settore meridionale; 2) altopiano di Poirino e Pianura di Alessandria; 3) attuale spartiacque tra Po e Tanaro.

scribes the whole Asti reliefs as the product of dissection of an erosion *glacis* shaped during the "Villafranchian"(4).

No reference is found in the literature to the deposits extensively distributed over higher levels of these reliefs and discovered during the course of this study (see later). The only remark is in the notes to the first edition of the "Asti" Sheet (Sacco, 1935). Here, between Rio Stanavasso and the scarp forming the Western border of the area, he mentioned the presence of: a "strip of more or less "ferrettizzati" pebbly-gravelly-earthy alluvia" covered with "coarse, impure yellowish silt and small gravel towards the base". These deposits are described by Sacco as "Diluvium" (= Pleistocene). It is interesting to observe that Sacco states that the same type of deposits constitutes the surface of the Poirino Tableland and partially of the Alessandria Plain (Fig. 1).

Sacco's notes also state that "the Villafranchian is often covered, almost discontinuously, with transgression due to erosion, by Pleistocene deposits", represented by a undefined "mantle of silt representing the fine deposit of material held in suspension by the Pleistocene floodwaters" (Sacco, 1935).

(4) Gabert also regards the Villafranchian as partly Pliocene and partly Quaternary (op. cit., p.4).

Many years later, Carraro (1976) formulated the view, on both morphological and lithological grounds, that, before the last glaciation, the outflow of the Southern Piedmontese basin took place to the South of the Turin Hills through an area now occupied by the Poirino Tableland, Asti Hills and Alessandria Plain. Now it is collected by the section of the Po upstream from the present confluence of the Tanaro.

This hypothesis was first confirmed by the observation on the Poirino Tableland of the relics of a meandering stream net with a kilometric curvature radius (Forno, 1980). Next came the demonstration of the fluvial nature of the deposits associated with these remnants and their attribution to the Middle Pleistocene (Forno, 1982). The present paper falls within the line of research originating from these papers.

3. MORPHOGRAPHY

As mentioned earlier, the area under examination corresponds to the "Asti Reliefs". This term is used here solely in a geographical sense to indicate the hilly area known in the geological literature as the "Asti Basin". It includes parts of both the Upper and the Lower Monferrato.

Fig. 2 - Val Maggiore near Cantarana. Typical appareance of the valley of the Asti region: the wide, flat-bottomed valley is several kilometers across and accomodates a brook visibly underfit in relation to the size of the valley.

Val Maggiore nei pressi di Cantarana. Tipico aspetto dei fondovalle principali nell'Astigiano: l'ampia valle a fondo piatto ha una larghezza media di alcuni chilometri ed è percorsa da un rio vistosamente sottodimensionato rispetto all'incisione che lo ospita.

The area extends westwards from the city of Asti over about 600 square kilometres. It is bounded to the East by the watershed between the Tanaro and the Po. Its Western boundary corresponds to the escarpment (lying roughly N-S in this section) that borders the Poirino Tableland to the East and also forms the asymmetrical watershed between the basin of the Rio Banna, to the West, and the Tanaro, to the East. The Southern and Eastern boundaries are devoid of morphological evidence.

The Asti hills slopes are mostly "concavo-convex" in Young's sense (1964), *i.e.* concave towards the summit and convex at the junction with the valley floor, with a gradual increase in gradient from top to bottom. They are separated from each other by wide, flat-bottomed valleys (Fig. 2) with an underfit stream net.

The valley incisions often display a generally asymmetrical transverse profile. Those running about NE-SW have slopes facing East steeper (10÷12°) than those facing South (6÷8°). Those lying roughly E-W are also slightly asymmetrical. The Southern slopes are usually steeper (12÷14°) than those looking to the East (7÷9°). This occurs, for example, for the incisions of Valmaggiore, Valle Artiglione and Val Baciglio, in Valle del Borbore and Valle del Triversa. The steeper slope of these incisions often decapitates the small valleys of the affluents of the adjacent drainage basin *(e.g.* along the Borbore river in the Vaglierano district) (Fig. 3). Locally, however, the steepest slope is that exposed to the ENE, as in some smaller valleys running NNW-SSE, such as Valle Manina.

The overall picture of the Asti Hills is one of modest relief energy. The highest sectors are found in the NW and SW portions, where the summit reach 540 meters near Albugnano and 360 meters near Cisterna d'Asti. The lower portions correspond to the succession of wide, parallel roughly E-W incisions of the Tanaro, Borbore and Triversa, which forms the central sector, where the summits attain 200 meters above sea level.

The ridges are usually elongated and often digitate; their orientation varies. They are elongated roughly NW-SE on the left side of the Borbore and the Tanaro, and roughly E-W in the area immediately to the South of the E-W section of the Tanaro, and on the right of the Borbore between Tigliole and San Damiano. They lie about SW-NE in the remaining Southern sector, though here a preferred orientation is often absent.

Their summits sometime have a rounded transverse profile; more commonly, however, especially in the Southern sector, true crests are observed. The longitudinal profile is generally interrupted by repeated changes of slope, giving rise to an alternation of subhorizontal and nearly vertical segments. Their number varies in the different drainage basin.

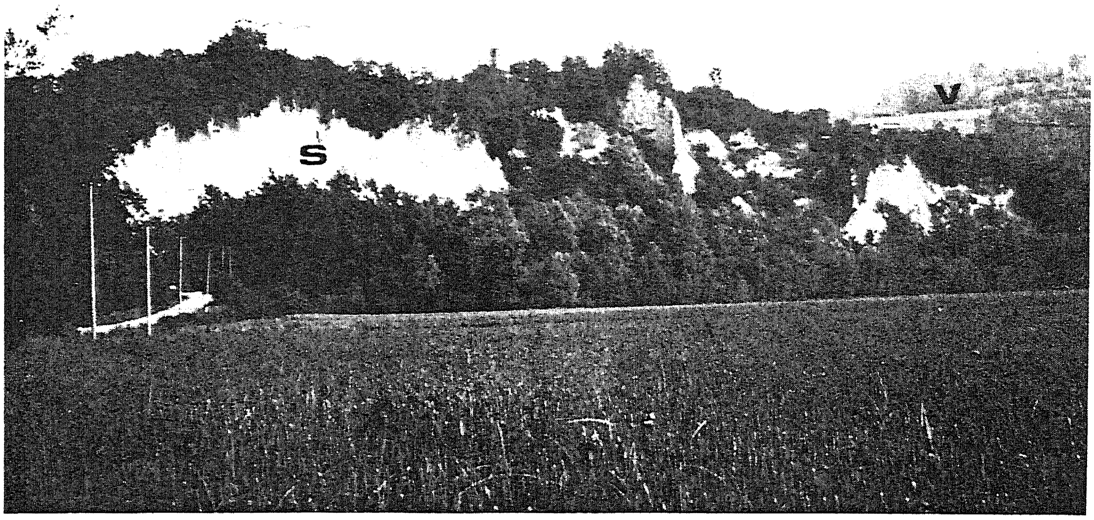


Fig. 3 - Right bank of the Borbore valley near Vaglierano. The valley, in this stretch running roughly NW-SE, is strongly asymmetrical in cross-section. Many secondary valleys (v) running in an East-West direction, are cut by the steeper right hand slope (d), locally represented by near-vertical scarps.

Versante destro della Valle del Borbore nei pressi di Vaglierano. La valle, diretta in questo tratto circa NW-SE, è caratterizzata da una forte asimmetria nel profilo trasversale: il versante destro, a luoghi rappresentato da una scarpata subverticale (s), tronca, decapitandole, alcune valli secondarie dei bacini idrografici contigui, orientate prevalentemente E-W (v).

Some wide ridges are locally interrupted by saddles in the form of elongated depressions running accross the ridges. They have a flat bottom and are suspended several tens of meters above the present valley floor and do not carry watercourses.

The affluents on the left of the Borbore display a pinnate pattern, while those on the right display a parallel pattern with regard to the Tanaro. It can also be seen that the affluents on the right of the Borbore are fewer and smaller than those on the left[5]. A comparable asymmetry can be seen also in the affluents of the Tanaro to the East of the city of Asti, and in those of the Triversa on the Western border of the area. Here also, the right hand net is much less developed than the one on the left.

All the watercourses in the area have a sinuous pattern, with straight stretches sometimes associated with meandering.

Four main drainage flow directions can be detected: N-S and NW-SE in the Eastern sector, E-W in the central sector and SW-NE in the Southern sector.

Most watercourses are composed of sections whose flows follow these directions.

(5) There are no right-hand affluents at all between Pianetti and Asti.

4. METHODOLOGY

The Quaternary deposits of the Asti Hills are fine-grained (sandy silts, silts and clayey silts). They are pedogenized at different degrees and distributed in several altimetric bands. As it will be seen, they are often preserved at present in the form of colluvial products. Generally speaking, there is a direct relation between their degree of preservation, that of the erosional forms that were their original hosts and their altimetric distribution; this is particularly true when they are preserved *in situ.* The higher deposits display a more advanced pedogenetic evolution than the lower ones; the latter are more widespread and better preserved.

The suite of deposits outcropping in the Asti area has been divided into three complexes made up by different units which lie at variable altitudes: they correspond to successive sedimentation and terracing episodes. They will be described in § 5.2.

In addition to the deposits preserved in their original stratigraphic position, corresponding to flattish slope sectors ("*in situ* deposits"), have been also recognized, and shown on the maps, the sediments resulting from downwashings of deposits from higher, more ancient terraces ("colluvial products *s.l.* "). They can generally be

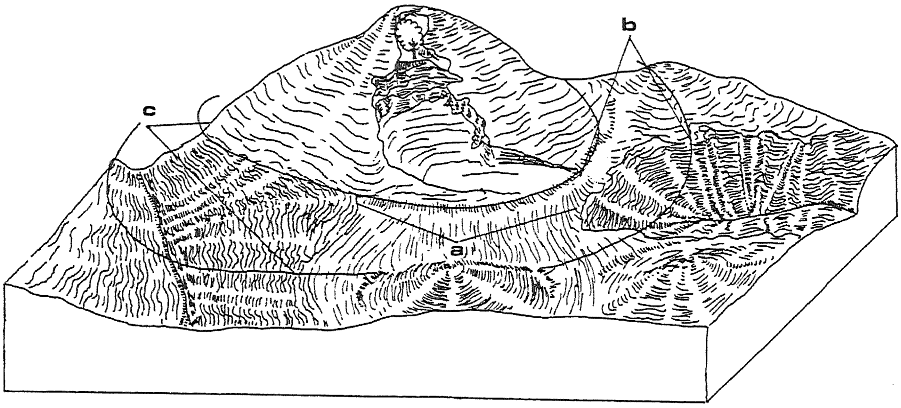


Fig. 4 - A fluvial channel relic (Complex A) preserved in Madonna della Neve-Calliano. These forms, which are relics of the configuration of the previous hydrographic system, are in various states of preservation: *i.e.*: the original morphology can be: preserved (more or less remodelled), partly or completely obliterated. It often happens that different evolutionary stages are still visible in a single segment of a channel. In the illustrated example, the segment whose morphology is better preserved corresponds to a flat-bottomed saddle (a) in which the colluvial deposits are preserved. This saddle is delimited by two faint reliefs corresponding to the original banks. The western segment (b) is presently being obliterated where a branch of the original secondary hydrographic system, by wearback erosion, cuts the original form. In this segment only traces of original deposits (colluvial products) are preserved. On the contrary, the western segment (c) has been completely reutilized by present-day river which has inherited the original direction and, by deepening the valley, has worne away the ancient deposits and has obliterad the original shape.

Relitto di canale fluviale (Complesso A) conservato in località Madonna della Neve-Calliano. Queste forme che fanno parte della precedente configurazione del reticolato idrografico, presentano gradi diversi di conservazione: la morfologia originaria può essere cioè talora preservata (se pur più o meno rimodellata), parzialmente cancellata o completamente obliterata; questi diversi stadi di evoluzione si osservano spesso anche nei singoli tratti di uno stesso canale. Nell'esempio illustrato il canale conservato è un meandro incastrato: il segmento in cui la morfologia originaria è meglio conservata è rappresentato attualmente dalla sella con fondo subpianeggiante in primo piano (a). I due rilievi che la comprendono corrispondono a quanto resta delle originarie sponde rispettivamente concava e convessa. Il segmento indicato con (b) è in via di progressiva obliterazione nel tratto in cui un ramo secondario del reticolato idrografico attuale, per erosione rimontante, ha intercettato la forma originaria; in esso sono conservate solo sporadiche tracce dei depositi originari (tasche di colluvium). Il segmento indicato con (c) è stato invece completamente riutilizzato da un corso d'acqua del reticolato attuale che ne ha ereditata la direzione e, approfondendovisi, ha asportato completamente i depositi ed obliterato la forma originaria mantenendone unicamente la direzione.

distinguished from the *in situ* deposits by their more porous fabric, and the occasional presence of stone lines, and carbonate and magnesium-bearing concretions. The erosion surface, separating the "colluvial products *s.l.* " from the substrate (represented by pre-Quaternary formations or older Quaternary deposits), is distinct, while it is always gradual in the "*in situ* deposits".

A cartographic distinction is also made in the map between "soil sediments" and "colluvial deposits *s.s.*": the former are a colluvium only slightly displaced. It has been introduced on account of the different interpretations it involves. A "soil sediment", in fact, is a deposit whose present altimetric distribution is not significantly altered and should not affect the interpretation. "Colluvial deposits *s.s.*", instead, are deposits generally preserved at the foot of the escarpment on which the parent material outcrops. These are very often covered by more recent colluvial products.

Furthermore, in the case of "colluvial deposits *s.s.*", it is not always possible to determine whether they are pedogenized and subsequently downwashed fluvial sediments, or rather soils that developed on a pre-Quaternary substrate and were similarly colluviated. At present, such soils are, indeed, sometimes preserved *in situ,* sometimes in the form of colluvial products. They are not shown on the map, unless they are chronologically meaningful (Complex "0").

The modelling of the Asti Reliefs consisted of a succession of terracing phenomena. These were carved by the hydrographic network draining in the "principal watercourse draining the Southern Piedmontese basin". The initial surface was represented by the depositional top of the Villafranchian series. The oldest terraces have been completely obliterated. The remodelling has variously altered the original configuration of those preserved: of these, the more ancient are only represented by slope changes of the valley side. The landscape can so be subdivided in a series of altimetric bands that are here characterized as "modelling units". These modelling units can be calibrated chronologically from their relation with deposits for which dating evidence is available.

The age, the distribution and the altimetric extent of modelling units can be used to reconstruct the stages of evolution of a given area. It is generally impossible to separate the role played by the three groups of controlling factors (climatic, geodynamic and lithologic) because the morphogenesis is the integration of their interplay. It is only in particular conditions, when one or two of the variables can be regarded as uniform for the entire area, that one can attempt a purely qualitative assessment of the "weight" of the third variable.

As far as the Asti area is concerned, the erodibility of its lithologies is relatively uniform, while its small dimensions suggest uniform climatic variations over the time span in which the terraces sequence was formed. It can thus be supposed that, for basins of equal size and over the time period considered, the differences in the number of terracing episodes and their altimetric distribution are due mainly to differences in geodynamic activity.

Air photos of the Asti Hill have revealed forms that can be referred to relatively well preserved and variously remodelled sections of river channels (Fig. 4). The reliability of the genetic interpretation of these forms varies in relation to the inverse ratio between their height (and age) and their degree of preservation. On the geological map, different symbols are used to indicate "certain", "probable" and "presumed" fluvial forms. The "certain" forms include segments of paleovalleys or those now suspended above the valley floor with a greater or lesser part of *in situ* deposits. "Probable" forms are saddles distributed at relatively comparable heights and similar to forms preserving strips of fluvial deposits in neighbouring areas. Lastly, "presumed" forms are those solely corresponding to a series of morphological features, such as counterslopes on the valley sides, that cannot be unequivocally explained, though there is a relative correlability of their heights of preservation.

In each case, the exact original configuration, *i.e.* the shape of the channel, and above all the direction of flow, cannot be directly deduced from the remodelled forms. Thus, these are evidence of different configurations of the stream net. These have become interlinked, over the course of time, and often appear controlled by flow volumes and rates that are sometimes very different from those of today.

5. LITHOSTRATIGRAPHY

5.1 The pre-Quaternary substrate

The Pliocene-Quaternary evolution of the "Asti Basin" passed through two different cycles(6):

- the Lower Pliocene-Lower Pleistocene cycle, which began with an ingressive episode (the Piacentian facies) and ended with the classic regressive sequence dated from the succession of the Astian and Villafranchian facies. A general feature of the cycle is relatively fine, continuous sedimentation, interposed with primarily horizontal erosion surfaces;
- the Middle Pleistocene-Holocene cycle, marked by extremely discontinuous deposition episodes, separated by stronger, continuous and mainly vertical erosive episodes. This type of evolution has given rise to a typical terraced series carved into the deposits of the first cycle.

In this paper the Plio-Villafranchian deposits and the terraced sequence of the Middle Pleistocene - Holocene cycle are referred to as the "substrate" and the "cover" respectively(7).

The substrate also was surveyed in the course of this study.

The main lithological and structural features are described below. The original data that emerged from the survey are shown for each formation.

The Asti Hills are mainly carved in the semicoherent deposits of the classic Neogene series:

- in the central-Eastern and Southern sector, the Astian sands;
- near the Eastern boundary, the clayey marls with small, intensely tectonized, intercalated Messinian selenitic gypsum lenses;
- in the western sector, the polygenic Cassano Spinola conglomerates, which are formed of well-rounded, decimetric marly limestone pebbles, Upper (Lower?) Pliocene sandstone and lower (Martinis, 1954) or Middle (Boni & Casnedi, *op. cit.*) Pliocene marly-silty clays.

Elsewhere, the hills are primarily composed of silty-clayey of the Villafranchian facies.

The Asti sands are fine to coarse and usually organized in layers of decimetric to metric (up to 3 m) thickness, marked by plane-parallel surfaces. There are local marly intercalations and levels formed of loose gravel (Fassi di Bramairate). Some discontinuous levels are particularly rich in marine molluscan fauna.

The complex of Villafranchian sediments is preserved to constitute part of the Western sector of the hills that includes the fossiliferous districts of Villafranca and Cantarana, which yielded the well-known remains of Vertebrates. The complex is composed of two units:

- a lower, mainly sandy-gravelly unit, regarded as a delta product; this is known as the Fossanian facies, which is a local heteropic facies of early or "warm" Villafranchian;
- an upper unit (Late Villafranchian or "cold" Villafranchian), consisting of "clayey-marly and sandy" deposits associated with "gravelly and sometimes conglomeratic deposits" (Boni & Casnedi, 1970) of a "fluvial-lacustrine environment"; this is indicated by freshwater and land molluscs, and by the roots of plants still preserved in their original position (Pavia, 1970).

The transition from the deposits in the Astian facies to those in the Fossanian facies is often gradual, though

(6) This type of succession is common to the whole of Piedmont (see Allason *et al.* , 1981) and much of Italy (see Ambrosetti & Carráro, 1980).

(7) The map accompanying this study shows the divisions and distribution of the cover. Its age is informally given as Middle and Upper Quaternary.

erosional type contacts are visible locally (Tigliole-Malaterra road).

The upper term of the succession outcrops in the immediate vicinity of Villafranca d'Asti. It consists of silts and clayey silts particularly rich in fossils (phyllites from the Arboschio quarry, near Cantarana), with intercalated gravel lenses. A recent review of the subject (Carraro *et al.*, 1982) has shown that the deposits of the Fossanian facies are separated from those of the Villafranchian facies *s.s.* by an erosion surface that emphasizes a weak angular discordance, recognizable only regionally on the map. At this point, there is a hiatus in the series, which includes the Plio-Pleistocene boundary.

The gravelly deposits are mainly composed of quartzite pebbles and of white and pink conglomeratic quartzites. These are sometimes markedly corroded, generally < 4 cm, though up 7 cm locally (Nigra di Ferrere), and embedded in a sandy matrix. An oblique foliated stratification is clearly visible in some outcrops (Castellero-Bricco Trombetta road).

These deposits are intensely altered through their entire thickness, which usually ranges from a few decametres to about ten meters. They are dark red in colour (from 5YR 5/6 to 2.5YR 4/6 on the Munsell Soil Charts), are heavily enriched with clay and ferruginous and/or manganesiferous concretions.

5.2 The Quaternary cover

The Asti Quaternary deposits have been divided into a series of informal "complexes", mainly in the light of their altimetric distribution and pedological nature. Minor divisions referred to as "units" are occasionally introduced.

The thickness of the colluvial products is always small (max 1 m). It would also appear that the original sedimentary bodies must have been no more than a few meters thick. The present series is thus a succession of essentially erosional terraces. The scarps separating the depositional episodes have a decidedly higher altimetric development compared with the thickness of the sedimentary bodies and are therefore mainly carved in the substrate.

The scarps have been mapped in classes by altitude and distinguished by symbols. Colours are used to indicate their age, *i.e.* the age of the two sedimentary bodies between which they are comprised and hence that of their original modelling. While an erosional episode preluding the formation of an accumulation terrace is in progress, a sedimentary body is forming at the same time downstream. Its chronology is therefore equivalent to that of the scarp modelling. Just, as the upper limit of the interval during which a sedimentary body is deposited corresponds to the age of the soil developed on its deposition surface, so the lower limit is represented by the age of the soil developed on the terraced surface suspended immediately above it.

This approach has been employed in the recent studies on the Piedmont Quaternary. Its application to the Asti Hills has led to the construction of a local pedostratigraphic scale. The stratigraphic divisions shown on the map are thus of strictly local significance. To facilitate the correlation of these results with those for the nearly Poirino Tableland (Forno, 1982), the following table illustrates the approximate chronological correspondence between the two local scales.

Table 1

Poirino Tableland (Forno, 1982)	Asti Reliefs (present paper)
Complex C	
Complex B	Complex C
	Complex B Unit B2
	Unit B1
Complex A Unit A2	Complex A
Unit A1	
("colluvial clayey-silty intercalations")	Complex 0

On the assumption that the pedogenesis was continuous (see § 4), and since even in neighbouring hydrographic basins, the number of terraces (*i.e.* pedogenesis episodes) is not the same, it follows that there may not be correspondence between different pedostratigraphic sequences, and in particular that the soils of different terraced sequences in different basins will probable differ from each other. This fact, however, cannot be appreciated when are used colour charts, whose variations are based on a discontinuous series of values. The complexes thus include units belonging to time spans that are not precisely defined, but can be regarded as approximately coeval due to the relatively long period involved (Carraro *et al.*, in press).

It must also be added that the field data show that in the same evoluted morphological basin, *e.g.* that of the Versa, deposits referable to a single complex display local differences in pedogenetic evolution (increasing in this case downstream) that can sometimes be brought out even only with the use of colour charts. This suggest that the rate of modelling may be sometimes comparable to that of pedogenesis.

5.2.1 Complex "0"

This comprises the oldest deposits recognized in the local sequence. These are solely preserved as colluvial lenses extending a few square meters at most, and usually less than 1 meter thick. They are located up in the slopes or, more commonly, they are intercalated at various levels in the lower, younger deposits.

They are clayey silt deposits devoid of a distinct fabric. Their mean colour index is 2.5YR throughout their preserved thickness. They also display diffuse secondary greyish variegations (pseudogleys).

The boundary between these deposits and the substrate is always sharp. It is emphasized by occasional centimetric carbonate concretions and more frequently by blackish manganese oxide concretions, irregular and subspherical in shape. These are distributed in such a way as to form more or less continuous levels inside the deposit where the substrate is characterized by greater impermeability.

The colluvial lenses recognized and mapped are distributed relatively evenly over the area. Nevertheless, it is reasonable to suppose that they are only a very small part of those present, most of which are presumably buried under colluvial deposits that are more recent and hence cannot be directly observed. On some occasions, they are fortuitously detected during house building operations, as occurred near Cisterna d'Asti.

The deposits from which they are derived must have been originally distributed in the altimetric belt where is developed the relief conventionally called "paleo-landscape" in the geological map. In view of their high degree of pedogenization, however, and their advanced reworking (they are on all occasions colluvial product *s.s.* as this term was explained in § 4), it cannot be determined whether they are Quaternary river or wind-borne sediments that were pedogenised and subsequently washed down, or pedogenetic products lying on a pre-Quaternary substrate, subsequently colluviated.

Fig. 5 - Fluvial deposits of Complex A preserved *in situ* (Fassi quarry in Bramairate). In the silty clay outcrop (with color 5 YR 4/6-5/8), now destroyed by quarrying, the fluvial silts erosional bottom (in wich scattered coarser fraction was found), modelled on Villafranchian deposits, can be seen.

Depositi fluviali del Complesso A conservati in situ (Cava Fassi di Bramairate): nell'affioramento di limi argillosi (colore 5 YR 4/6-5/8), attualmente distrutto dal procedere dei lavori di cava, è ben visibile la base erosionale dei limi fluviali (nei quali sono stati rinvenuti ciottoli centimetrici dispersi) modellata su depositi in "facies villafranchiana".

5.2.2 Complex A

This comprises the oldest and highest recognized in situ deposits in the terraced sequence.

It is rare for them to be preserved strictly in the primary portion. The most significant deposits are those of the Fassi quarry at Bramairate, near Baldichieri (see Fig. 5). In these cases their morphological expression is represented by subhorizontal surface strips (tabular summits of the ridges), due to the dissection of the originally continuous depositional surfaces. They are more frequently preserved as "soil sediments" or "colluvial deposits *s.s.* ".

The weathering thickness of the in situ deposits is about 2 meters (at Castiglione). In the case of soil sediments and colluvial deposits *s.s.*, the colouring is relatively uniform, though the thickness variegations are common. The structure of these deposits, including those preserved *in situ*, is clearly of secondary origin, *i.e.* pedogenetic. They consists of prismatic aggregation emphasized by thick, widespread coatings of manganese oxides.

The Complex A deposits are randomly distributed everywhere throughout the area, with the exception of the sector at its SW boundary. This last sector should have represented a "paleorelief" while these sediments were being deposited due to its higher relative altimetry.

The degree of preservation, on the other hand, is extremely varied from one point to another. These deposits, however, display good preservation and relatively continuous distribution in limited areas even though soil sediments predominate here as well (Tigliole to the SW of Asti and in the Malaterra district).

The height of the modelling unit where these deposits are preserved ranges from 350 m on the Eastern to 240 m on the Southern boundary. The unit also forms a roughly E-W belt in the centre of the area, where the Complex A deposits are preserved at an average height of 208 m (Cravera district). This is the lowest point for the distribution of these deposits.

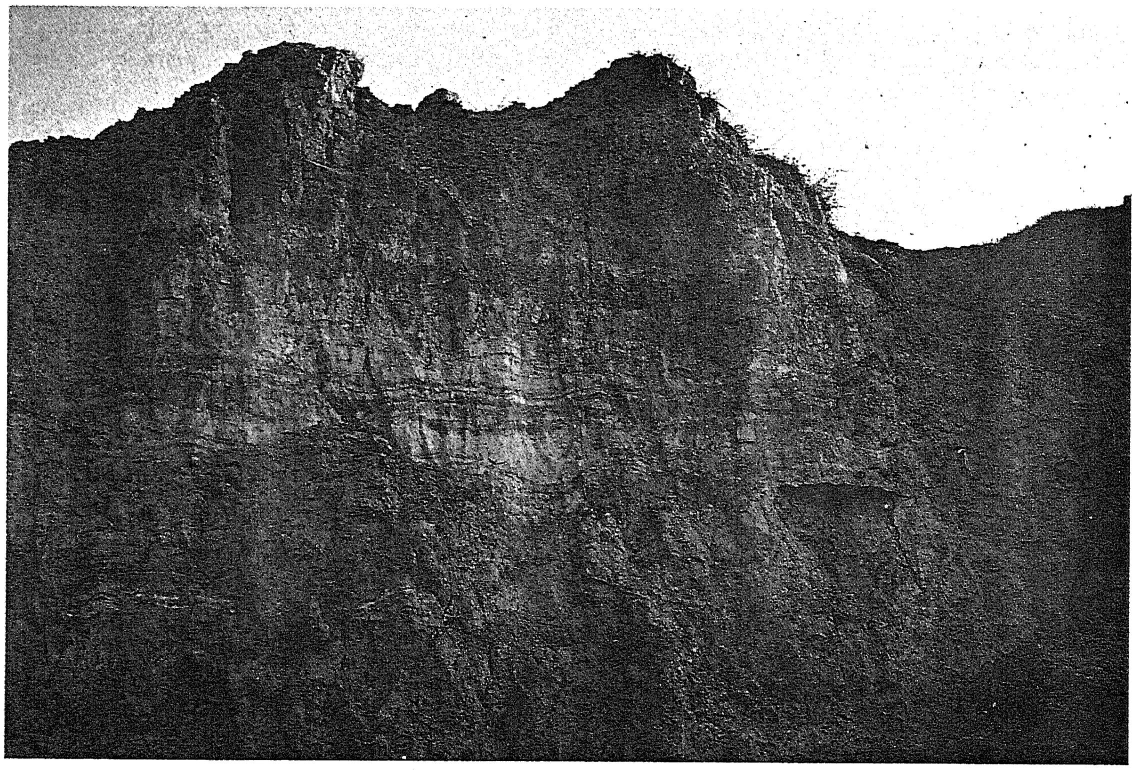


Fig. 6 - Outcrop of fluvial deposits of Complex B (B1 Unit) near Cascina del Muto (Baldichieri). The deposits are composed of sands and silts (colour: 7.5 YR 4/6), their thickness is about 4 m and they are *in situ* deposits. They form a tabular surface about 40 m above the valley floor of the present day Borbore river.

Affioramento di depositi fluviali riferibili al Complesso B (Unità B1) presso Cascina del Muto (Baldichieri): si tratta di alternanze di sabbie e limi sabbiosi con colore 7.5 YR 4/6, potenti circa 4 m, conservati in situ: *la loro espressione morfologica è rappresentata da una superficie subpianeggiante sospesa di circa una quarantina di metri sul fondovalle attuale del T. Borbore.*

The gradual drop in height in the central sector is due to the reduction of the height of the scarps separating the Complex A deposits from the younger, lower Complex B deposits *(i.e.* the "converging scarps" of Bortolami *et al.*, 1978). These run from East to South in the Eastern and vice versa for the Southern sector: Complex A is separated from Unit B1 by a 50÷65 m scarp in the Eastern sector and a 30÷60 m scarp in the Southern sector, whereas in the elongated E-W central sector (Fassi di Bramairate) the relationship becomes one of direct superposition without the interposition of a scarp.

The Complex A lithology is mostly silt (50%), clay (40%) and sand (5%). A coarser fraction scattered throughout the sediment is represented by few per cent of clasts and concretions. The major clasts are pebbles, mostly greenstone (prasinites, usually patinated with iron oxide), as well as other lithotypes, possibly intrusive basic rocks, that cannot be identified on account of their deep weathering. The size of this coarse fraction is between 0.5 and 3 cm. The degree of sphericity varies very considerably: the pebbles are usually well rounded, though flat forms are sometimes encountered.

The coarse fraction also includes small (40÷60 mm) quartz pebbles with a high degree of roundness and sphericity reminiscent of the surface deposits of the adjoining Poirino Tableland (Forno's Unit A2) and hence comparable in origin and chronology.

The common characters of these deposits are the poor granulometric sorting and the presence of a coarse fraction, composed of both spherical and rounded granules and rounded but poorly spherical granules, different in shape and lithology from the coarse fraction in the substrate. This, when taken in conjunction with the erosional nature of the basal surface in the few relics of *in situ* deposits, rules out that the Complex A neither developed as a soil at the expense of the substrate nor that it was deposited by wind. It is thus clear that these fine grained deposits are fluvial sediments. Maximum thickness is of the order of 3+4 meters for both *in situ* deposits and soil sediments. In the case of true colluvial products, on the other hand, the thickness varies greatly and it is usually impossible to assess, since they form lenses "wrapped" in a matrix formed of more recent colluvial materials, mostly derived from soils developed on the substrate.

Examination of the areal distribution of the Complex A deposits, preserved on both sides of the present valleys, shows that the valley of which they originally represented the bottom, must have run about E-W between the scarp that now forms the Eastern boundary of the Poirino Tableland and Rio Rilate (East of Asti). Part of this valley has been inherited by the present segments of the Borbore and Triversa running in the same direction (for details, see § 7).

The distribution in bands running roughly N-S and NW-SE and dipping towards the central sector[8] of these deposits in the Eastern and Southern sectors of the Asti Hills, shows that they can here be regarded as fluvial deposits of secondary branches of the ancient stream network, affluents of the main collector running approximately E-W.

In addition to fluvial deposits and their colluvial reworking products, soils with a mean colour index of 5YR 5/8 and sometimes with variegations up to 2.5YR 4/6 developed even on the substrate; these can be assigned to Complex A in this area by reason of their pedogenetic features and hence for their age. They are often preserved in a primary position and their preserved "thickness of alteration" is usually a few meters. They are generally developed on the Pliocene formation in the Fossanian facies and thus have a much coarser grain size than the fluvial deposits of the same Complex A. They are, in fact, composed of medium grained sands and abundant gravel, mostly formed of centimetric quartzites and "anagenites" and are therefore readily distinguishable from the fluvial deposits.

It was decided not to include these soils on the map so as not to impair its legibility. Generally speaking, they can be related to periods of relative stability. These soils, unlike the soils developed on the fluvial deposits, can not be used for the chronological interpretation.

[8] This dip can in fact be partly seen as certainly primary; in part, however, it is due to postmorphogenetic geodynamic activity.

5.2.3 Complex B

This comprises the products whose original position was immediately lower that of Complex A: their altimetric distribution band is always entrenched within the Complex A deposits.

Their colour index is around 7.5YR. They lie, however, on two altimetric bands and are therefore divided into Unit B1 and Unit B2.

They are composed of silts (60%) and sands (40%). The coarse fraction of the Unit B2 deposits is partly formed of distinctly rounded serpentine fragments, with 0.3+0.6 cm (Cerratone district), and carbonatic concretions. The latter forms the entire >400 µm fraction in the Unit B2.

The presence of an albeit scanty coarse fraction and the openly erosional nature of their basal surface mean that they can be regarded, with reasonable certainty, as fluvial deposits.

Unit B1: the colour of these deposits is 7.5 YR 4/6 and 3/6. Their thickness varies considerably with a maximum of not more than 3 meters *(e.g.* Collina del Muto, near Baldichieri) (see Fig. 6).

Their degree of preservation is usually comparable with that of Complex A. *In situ* deposits forming tabular summits and terraced surface on the ridges are rare; most deposits are soil sediments.

Their areal distribution points to their genetic link with a drainage system composed of a W-E main collector and a valley floor about 3 km wide. Traces of this system (abandoned channels variously reused and remodelled) have been recognized everywhere in the Asti Hills. Although its flow direction lines are much the same as those of the modern net, the latter can be regarded (apart from the Tanaro) as local, *i.e.* with a small drainage basin, whereas these paleo-collectors served to drain the entire Southern Piedmontese basin via the present Poirino Tableland. In this an analogous "local" net, that has inherited the main downflow lines of the previous net, is developing. In this case, however, there has been an inversion in the flow direction of the main collector (Forno, 1982).

Unit B2: these deposits have a mean colour index of 7.5YR and are 3+4 meters thick. They include the Quaternary deposits marked on the second edition of the "Asti" sheet (Boni & Braga, 1970) near the districts of Pianetti and S. Giulio.

They are generally preserved as soil sediments forming relics of terraced surfaces running for up to several hundred meters. These are separated by incisions some tens of meters deep at the branches of the present stream net, but are readily related to each other geometrically.

Once again, *in situ* deposits are rare. This is partly due to very poor outcropping as a result of extensive

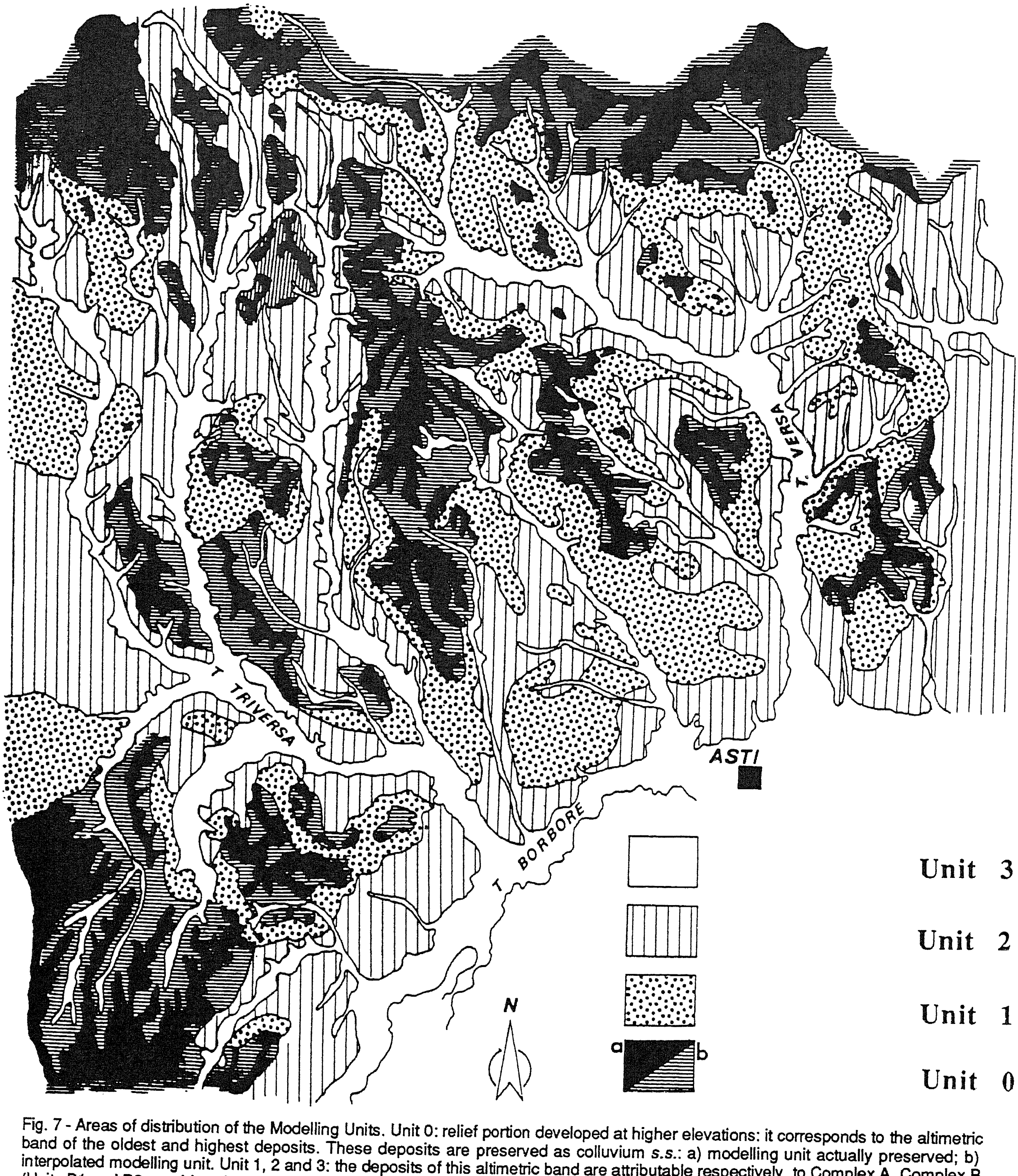


Fig. 7 - Areas of distribution of the Modelling Units. Unit 0: relief portion developed at higher elevations: it corresponds to the altimetric band of the oldest and highest deposits. These deposits are preserved as colluvium *s.s.*: a) modelling unit actually preserved; b) interpolated modelling unit. Unit 1, 2 and 3: the deposits of this altimetric band are attributable respectively to Complex A, Complex B (Units B1 and B2 considered together), and Complex C (deposits of the present day valley floor).

Areali di distribuzione delle Unità di Modellamento. Unità 0: porzione di rilievo che si sviluppa alle quote più elevate, corrispondente alla fascia di distribuzione altimetrica dei più antichi e più alti depositi, attualmente conservati allo stadio di colluvium s.s.: a) areale attualmente conservato; b) areale interpolato. Unità 1: porzione di rilievo corrispondente alla fascia di distribuzione altimetrica dei depositi del Complesso A. Unità 2: porzione di rilievo corrispondente alla fascia di distribuzione altimetrica dei depositi del Complesso B (considerando le Unità B1 e B2 nel loro insieme). Unità 3: porzione di rilievo corrispondente alla fascia di distribuzione altimetrica dei depositi del Complesso C (depositi che costituiscono gli attuali fondovalle).

farming and cultivation in their distribution area, and also because these deposits, too, have not preserved their original fabric. This is very clear on detailed examination: a hand-drill providing continuous samples for the first meter shows that reworking in fact took place throughout its thickness. This indicates the importance of reworking, even for short periods. The surface corresponding to the morphological expression of these deposits, generally displays weak undulations, and may thus be supposed to have been marginally affected by remodelling.

Unlike Complex A and Unit B1, the areal distribution of the Unit B2 deposits is essentially that of the present drainage net. This is true for both the main and the secondary branches.

Soil developed on substrate whit pedogenetic features comparable with those of the Complex B deposits (mean colour index: 7.5YR) are also present. The substrate is usually made up of deposits in Astian facies or of pre-Pliocenic deposits, on the Eastern boundary of the area.They are preserved both *in situ* and as colluvial products *s.s.* In the first case, they are about 1 meter thick; in the second, they represent a thin veneer.

5.2.4 Complex C

This comprises the clearly fluvial deposits forming the present valley floors. They are generally composed of silt and sands interspersed with subordinate centimetric gneiss, quartzite and anagenite pebbles, inherited from the local substrate. At the main collectors, these are predominantly centimetric gravels. Their thickness can never be directly observed in outcrops, but can be assessed around several meters from data provided by wells drilled in the alluvial deposits of the Tanaro.

The soils are yellow-brown in colour (10YR to 2.5YR 4\6÷6\8).

The present river beds are barely, if at all, entrenched within these wide valley floors. This is the cause of frequent flooding.

6. CHRONOSTRATIGRAPHY

The pedostratigraphy approach is the only means for attempting to establish the chronology of these Quaternary products.

The local pedostratigraphic series was calibrated with geological data from neighbouring areas. This process obviously takes account of the fact that the age of a soil developing on a deposit represent the minimum age of the deposit itself.

Since the various lithostratigraphic complexes recognized and mapped correspond to as many pedostratigraphic units, they will be described below using the same division as before. The chronological elements available for the calibration of each complex will also be discussed.

6.1 Complex "0"

Since this is always present in the form of colluvial products, it is never in a primary superposition relationship with datable substrates.

The literature data on the Quaternary of Northern Italy, however, can be used as indirect evidence for the dating of these products. First of all, the discovery of an Acheulean industry in the loess overlying soils with these characteristics "makes it impossible for these soils to be later than last glaciation" (Cremaschi & Orombelli, 1982). Furthermore, the fact that the lake deposits of Bagaggera (Lecco morainic amphitheatre), which contain the Matuyama-Brunhes paleomagnetic inversion, fossilized formations involved by soils of this type (Billard *et al.*, 1983) and that the Leffe lake deposits (Bergamo), as a whole older than the Matuyama-Brunhes limit, lie in a basin dammed by a formation with a relic soil of this kind (Billard *et al.*, op.cit.) shows that deposits with a 2.5YR mean colour index are certainly older than the 730,000 yr b.p., assigned to the inversion.

Lastly, the formation of soils with a similar colour index in the Emilian Apennines (Ambrosetti & Cremaschi, 1976; Cremaschi, 1982) has been referred to a time span ranging back either to a minimum of 400,000 yr or to a maximum unidentified moment preceding the Matuyama-Brunhes inversion.

In conclusion, this pedostratigraphic complex can be referred to a time span between about 1,000,000 and 400,000 years b.p., or in other words, to the upper part of the Lower Pleistocene or the lower part of the Middle Pleistocene.

6.2 Complex A

This is the oldest complex which, in the Asti area, is composed of *in situ* deposits.

The evidence for its dating comes from the discovery of remains of *E. primigenius* along the scarp marking the Eastern boundary of the Poirino Tableland. Originally the subject was studied by Zuffardi (1913); their assignment to the upper part of the Middle Pleistocene has recently been confirmed by Ambrosetti (pers. comm.).

Their exact provenance is not certain. Nevertheless, the formation that contained them has been assimilated to a lithostratigraphic unit whose soil is comparable with that of the Complex A deposits. This dating is also in line with the discovery of a level with volcanic glass (tephra) fragments in another formation with a comparable soil, namely the Torrazza Silts, Vercelli (Gruppo di Studio del Quaternario Padano, 1976). Its refraction index (1.54÷1.53) indicates a 55÷60% silica content. This can be correlated with an episode of volcanic activity of Monte Amiata Volcano, dated between 400,000 and 200,000 y b.p. (Bigazzi *et al.*, 1981).

This age can thus be taken as the earliest starting point for the genesis of the Complex A deposits, *i.e.* the upper part of the Middle Pleistocene. The minimum age can be deduced from the numerous prehistoric industries found in the Trino area on erosion surfaces modelled on similar deposits (Gruppo di Studio del Quaternario Padano, 1976; Giraudi & Venturino, 1982). The oldest of these industries has been assigned to the Lower Paleolithic (about 200,000 y. b.p.).

6.3 Complex B

Here too, there is no geological evidence from which a date can be established directly. The maximum age can be determined only indirectly, as corresponding to the minimum one for the Complex A pedogenesis.

As far as the minimum age is concerned, the rich bed (with a soil having, just like Complex B, a colour index of 7.5+10 YR) lies on Southern flank of the Turin Hills at Moncucco Torinese, immediately to the West of the Asti Hills. Examination of its fauna (molluscs, vertebrates, small mammals) and flora (woods, fungi, pollens) coupled with the 14C and amino acid datings, has given an age of 40,000±6,000 y b.p. (Alessio *et al.*,1982). This corresponds to the Upper Pleistocene and it is also the minimum age of Complex B.

6.4 Complex C

Here pedostratigraphic criteria cannot be used because the soils are insufficiently evolved. It is only possible to say that sedimentation must have taken place after that of Unit B2 (Upper Pleistocene), since Complex C is entrenched in this unit. It is thus the result of a succession of events that have taken place during the Upper Pleistocene and the Holocene[9].

7. MORPHOSTRATIGRAPHY

The Asti Hills comprise four "modelling units" as defined in § 4. Their distribution is illustrated in Fig. 7. The primary modelling of each unit has been dated from the chronostratigraphic data of their associated deposits.
These four units will now be described, starting with the oldest and hence the highest in term of altitude[10].

COMPLEX 1 -This part of the relief lies within original distribution band of the oldest and highest deposits preserved as colluvial products *s.s.* (Complex "0"). The pedological features of Complex "0" indicate that Complex 1 was modelled in the lower part of the Middle Pleistocene.

This Morphostratigraphic Unit (M.U.) has been conventionally referred to as a "paleo-landscape" on the geological map to show that it represents the product of remodelling[11] of the relief as it was when Complex A[12] was deposited. M.U.1 is fairly ubiquitous, though preserved in isolated remnants that are often of limited extent.

The "paleo-landscape", however, does not represent the product of remodelling of the entire relief as it was when Complex "0" was being laid down: subsequent evolution of the stream net, especially in the form of lateral migration, has led, locally, to its complete obliteration. These portions of M.U. are indicated with the symbol "b" on the map in Fig. 7.

The remodelling has greatly altered the primary configuration of the "paleo-landscape" and it is often fruitless to attempt to recognize and interpret relic forms. U.M. 1 was modelled in Middle-Upper Pliocene marine deposits and in Villafranchian facies deposits.

The envelopment surface of its remnants represents the "virtual" configuration of Complex 1, *i.e.* the configuration this unit would show as a result of tectonic deformation after its original modelling, had not supervened erosional remodelling. It is more or less flat, its slight undulations being referable, in line with what has been said in § 7, to both primary erosional features and subsequent deformation. It can be regarded as a form due to lateral fluvial erosion as those which subsequently were modelled by the stream net.

COMPLEX 2 - This comprises the altimetric band immediately below that of M.U.1. Its height varies considerably from one point to another. It is always entrenched with M.U.1 and can be divided into three sub units perched above each other: 2a, 2b and 2c. These are directly related to the fluvial deposits in Complex A and Complex B (Units B1 and B2), and to the deposits forming the present valley floors (Complex C).

These relations enable the primary modelling of the corresponding altimetric band to be referred to three time spans: lower *(p.p.)* to upper part of the Middle Pleistocene (Unit 2a); upper part of the Middle Pleistocene to the upper part of the Upper Pleistocene (Unit 2b); Upper Pleistocene to the Present (Unit 2c).
M.U. 2 is well represented in the Asti Hills, where it constitutes extensive sectors of the main valleys slopes. It is interesting to note that the number of units varies within individual valleys as well as between one valley and another. The planimetric and altimetric distri-

(9) The accumulation surface of these sedimentary body is still subject to occasional flooding.
(10) In Fig. 10, owing to difficulties in representation, the distribution of Units B1 and B2 is not indicated separately.

(11) It is obvious that both remodelling and the deformation that has taken place ever since its primary modelling have ensured that there is no correspondence between the present and the original planimetric and altimetric developments.
(12) One part of what is shown as Complex 1 may represent the relief already present during deposition of the Pliocene deposits, especially on the northern boundary. In some places (area to the north of Castelnuovo Don Bosco) this is rendered clear by traces of the Pliocene coastline.

bution of these sub units indicates that the basic pattern of the stream net has remained unchanged during the modelling of this M.U. In addition to natural deepening and backward extension of the original branches and the birth of new branches, evolution has taken the form of lateral migration of some watercourses, as well as changes in branch hierarchy provoked by a series of captures. As far as lateral migration is concerned, the fact that in most cases causes such as differences in the erodibility of the substrate or the introduction of sediments by the tributaries can be ruled out, means that the factor most commonly responsible of the lateral migration must be sought in differences in the synmorphogenetic geodynamic activity.

A higher uplift rate, for example, in the section where the right as opposed to the left side of a watercourse is shaped, has caused leftward migration within a valley cut. A single capture, on the other hand, cannot be explained in this way, since in addition to the factors mentioned above other parameters are involved, such as the size of the catchment basin and its orientation, etc. When these phenomena are examined as a whole within a definite chronological context, however, it is possible to detect the tectonic component as part of the general trend.

Lateral migration within a given valley can be recognized from its asymmetrical transverse profile. In the area examined in this study it is very common to find valley sections in which the various stages of the modelling process have been preserved, in the lower part in the form of terraces and in the upper part as breaks in the slope on one flank only, compared with the continuous and steeper gradient of the other side. In some instances, the asymmetry is inverted in different sectors of the some valley.

The numerous channels abandoned owing to capture are preserved. These relic forms are shown on the map by means of symbols indicating the degree of remodelling and by the same colours of the lithostratigraphic scale, showing how long they were active.

8. QUATERNARY EVOLUTION OF THE ASTI RELIEFS

As mentioned in the introduction, the Asti Reliefs lie between two flat areas (the Poirino Tableland to the West and the Alessandria Plain to the East) (see Fig.1). A continuous film of fluvial silts of variable thickness is distributed on both areas (Forno 1979; 1980; 1982; Terzano, 1985). Such film makes up a stratigraphic sequence referred, primarily on pedostratigraphical grounds, to the Middle Pleistocene-Holocene time span. The deposits of these two plains are similar in sedimentological, mineralogical-petrographic and pedological terms not only to each other, but also to those preserved on the terraced sequence of the Asti Reliefs (see § 5).

The genetic and pedostratigraphic correlability, however, does not match their altimetric distribution. Comparison of the altimetric development of the Asti Reliefs and the Poirino Tableland in a series of W-E profiles, shows that the terraced sequence preserved in the Asti Reliefs develops entirely at lower altitudes than the Poirino counterparts. The borderline between the two domains lies along the scarp marking the Eastern boundary of the Poirino Tableland.

This scarp is due to the development of the "Poirino Tableland marginal flexure": this development caused an inversion in the drainage flow during the Upper Pleistocene-Holocene.

A fluvial erosion-plain made up the unbroken junction between the Poirino Tableland and the Alessandria Plain at the beginning of the Middle Pleistocene-Upper Pleistocene (Fig. 8). The following differential uplift of the Asti region, as compared to the stable adjacent flat areas, produced the terraced sequence.

On the initial plain the main watercourse flowed from W to E. The relation between the hydrographic pattern and the Asti Reliefs for this time span is thus of antecedent type.

In the short time span immediately following (Holocene), the Asti Reliefs have been rapidly lowered tectonically relative to the Poirino Tableland. The scarp now marking the Eastern boundary of the tableland is the morphological expression of this structure. The axis of the newly formed structure (the "boundary flexure of the Poirino Tableland") is here trending approximately N-S. Its very recent age is demonstrated, among other things, by the virtual absence of wearback, as observed long ago by B. Castiglioni (1936).

A more detailed reconstruction of the evolution pattern can now be attempted.

The morphology of the present Asti Reliefs area during the Middle Pleistocene was that of a fluvial erosion-plain bounded by hills to the North and South. This plain was locally interrupted by gentle slopes (the "paleolandscape"). These, either represented the offshoots of the marginal reliefs or formed small, isolated hills (see Fig. 7). The erosional surface had been shaped by a drainage system whose basin was the entire Southern Piedmontese basin(13) This network had been superimposed on the aggradational surface of the Upper Villafranchian coastal marshes (see Terzano, 1985; Carraro *et al.*, in press). This last surface was completely obliterated in the sector corresponding to the present Asti Reliefs(14).

The main branches of this drainage system were

(13) This basin's main watercourse is now the section of the Po upstream from Turin.
(14) The "palaeorelief" on the map corresponds to the altimetric portion of the landscape modelled starting from this surface.

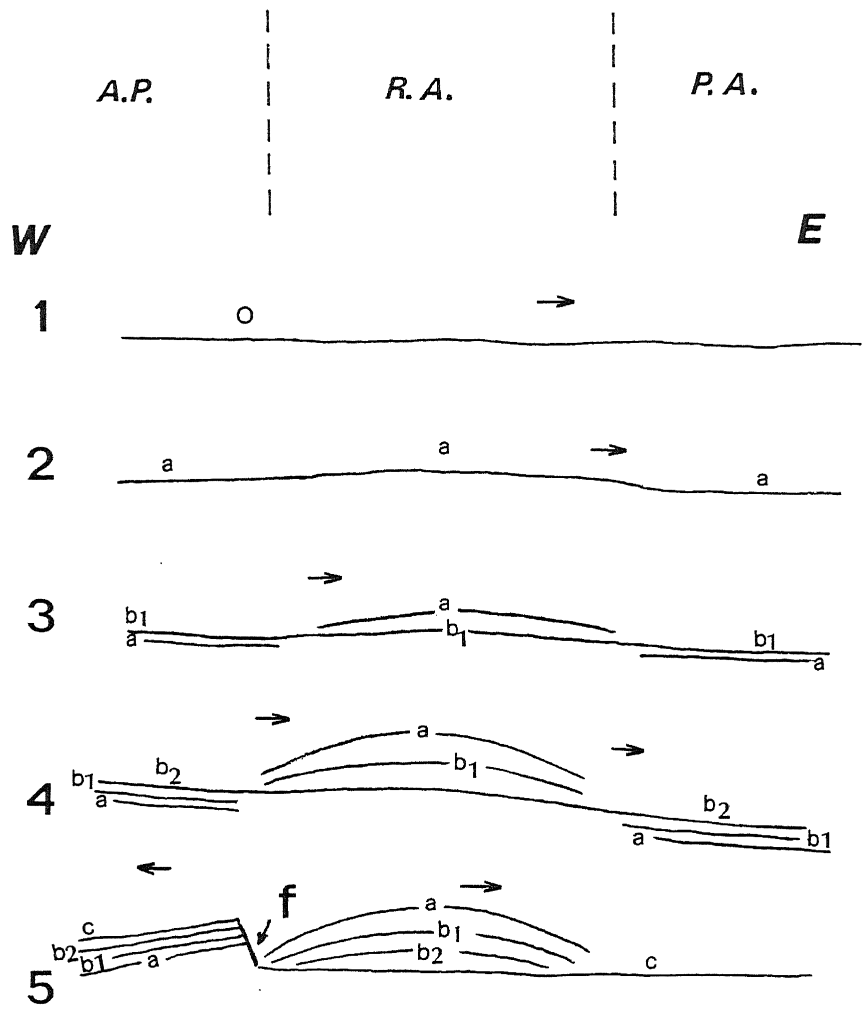


Fig. 8 - Scheme of the hydrographic system evolution in the sectors of Poirino Tableland (A.P.), the Asti Reliefs (R.A.) and the Alessandria Plain (P.A.) during the time interval Middle Pleistocene-Present: 1) during the sediment deposition of Complex O (lower part of Middle Pleistocene) the three sectors under consideration corresponded to a single fluvial-erosion plain in which the flow was from W to E (the arrows indicate the direction of flow of the main collectors); 2) during the sediment deposition of Complex A (middle part? of Middle Pleistocene), as part of the evolution of the Asti syncline, the Asti Reliefs were uplifted. These correspond to axial culmination of the main structure; 3-4) During the sediment deposition of Complex B (upper part? of Middle Pleistocene) the differential uplift of the Asti Reliefs relative to the neighgouring areas to the W and to the E, continued. As a consequence, the deposits of the Complex O, A and B constituted a sequence of terraces, whereas in the neighbouring areas appear to be superimposed; 5) subsequent to the deposition of the Complex B sediments, the sector of the Asti Reliefs was tectonically lowered relative to the Poirino Tableland with axis extending roughly N-S, the Asti Reliefs were lowered by the tectonics compared to the Poirino Tableland. This happened in correspondance with the newly formed structure (the Marginal Flexure of the Poirino Tableland (f) with a N-S axis). Consequently, the drainage direction of the Poirino Tableland area became inverted. The Poirino Tableland is now separated from the Asti Reliefs by the asymmetric watershed formed by the scarp which represents the morphological expression of the structure itself.

Schema dell'evoluzione del reticolato idrografico nell'Altopiano di Poirino (A.P.), nei Rilievi dell'Astigiano (R.A.) e nella Pianura Alessandrina (P.A.) dal Pleistocene medio all'Attuale. 1) Durante la deposizione dei sedimenti del Complesso 0 (parte inferiore Pleistocene medio) i tre settori considerati corrispondevano ad un'unica pianura di erosione fluviale nella quale i maggiori corso d'acqua, che avevano il proprio bacino di alimentazione nell'attuale Piuanura Piemontese meridionale, defluivano da Ovest verso Est (sono ricostruiti i collettori principali); 2) Durante la deposizione dei sedimenti del Complesso A (parte media del Pleistocene medio), nell'àmbito dell'evoluzione della Sinclinale di Asti si è verificato il sollevamento dell'area corrispondente ai Rilievi dell'Astigiano. Essi corrispondono ad una culminazione assiale della struttura principale; 3- 4) Nel corso della deposizione dei sedimenti del Complesso B (parte superiore del Pleistocene medio) è continuato il sollevamento differenziale dei Rilievi dell'Astigiano nei confronti delle due aree limitrofe verso Ovest e verso Est. In conseguenza a ciò i depositi dei Complessi 0, A e B costituiscono una sequenza terrazzata nei Rilievi dell'Astigiano mentre nei due settori limitrofi appaiono in rapporto di sovrapposizione; 5) Successivamente alla deposizione dei sedimenti del Complesso B, in corrispondenza ad una struttura di neoformazione, la "Flessura marginale dell'Altopiano di Poirino" (f) con asse diretto circa N-S, il settore dei Rilievi dell'Astigiano è stato ribassato tettonicamente rispetto all'Altopiano di Poirino. Di conseguenza è avvenuta l'inversione del senso di drenaggio nell'area dell'Altopiano di Poirino che appare ora separato dai Rilievi dell'Astigiano dallo spartiacque asimmetrico rappresentato dalla scarpata che rappresenta l'espressione morfologica della struttura stessa.

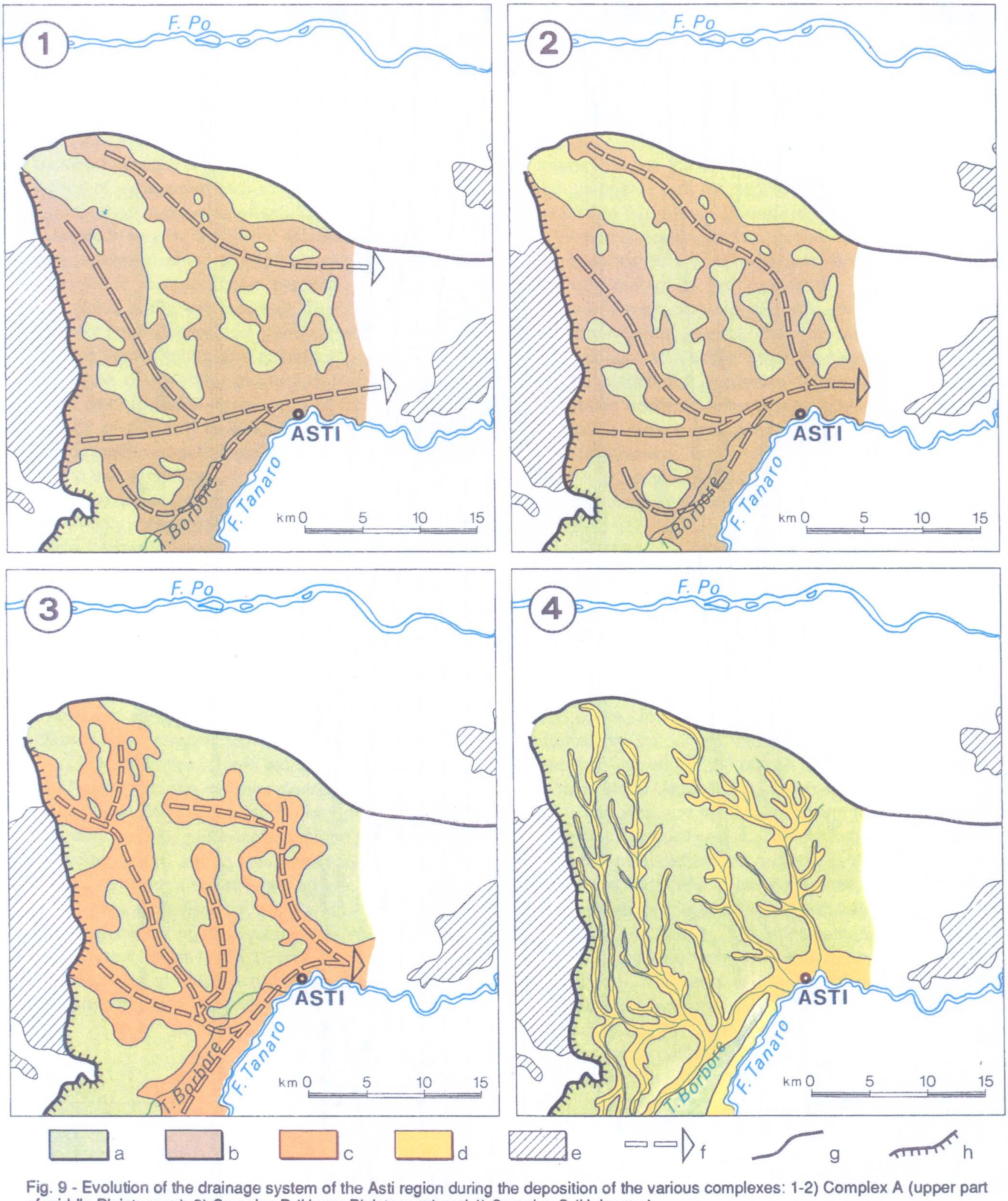
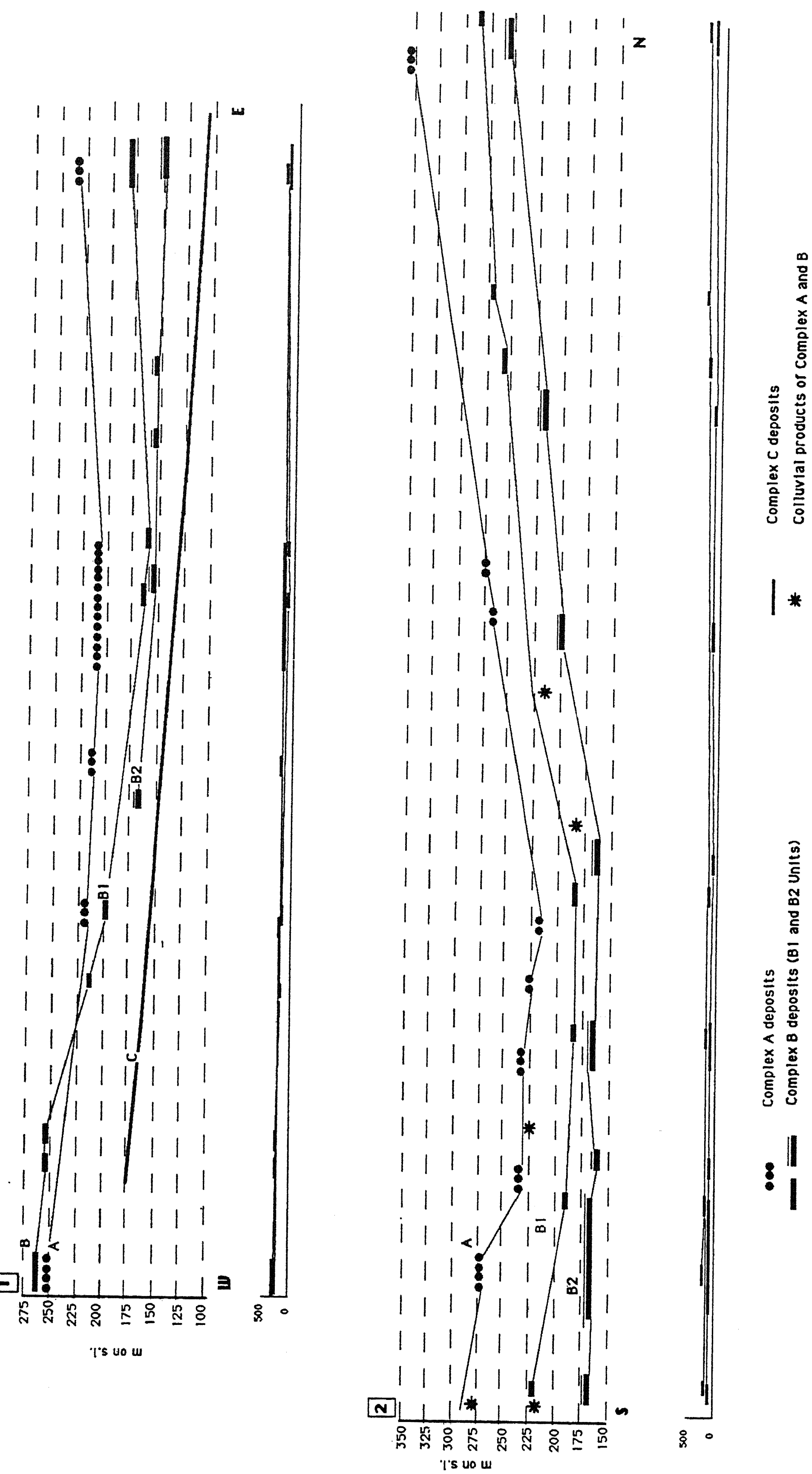


Fig. 9 - Evolution of the drainage system of the Asti region during the deposition of the various complexes: 1-2) Complex A (upper part of middle Pleistocene); 3) Complex B (Upper Pleistocene) and 4) Complex C (Holocene).

Evoluzione del sistema di drenaggio nell'Astigiano durante la deposizione dei sedimenti dei diversi complessi: 1-2) Complesso A (parte superiore del Pleistocene medio); 3) Complesso B (Pleistocene superiore) e (4) omplesso C (Olocene).


1
m on s.l.
275
250
225
200
175
150
125
100
W
E
B
A
B1
B2
C
500
0
2
m on s.l.
350
325
300
275
250
225
200
175
150
S
N
A
B1
B2
500
0
Complex A deposits
Complex B deposits (B1 and B2 Units)
Complex C deposits
Colluvial products of Complex A and B

represented by watercourses whose general flow line was eastwards, and whose traces (portions of meandering channels largely reshaped) are similar, as far as the fluvial morphology and size are concerned, with those of the present section of the Tanaro included in the area (see Fig. 9, stages 1 and 2). Subsequently, differential uplift led to a relief that inserted itself between the Poirino Tableland and the Alessandria Plain. The fact that the evolution of the Asti Reliefs, developed in confined conditions from both spatial and chronological points of view, enables the recognition of the tectonic synmorphogenetic component. The geodynamic activity that occurred after the fluvial erosion-plain was formed, now preserved as morphostratigraphic Complex 1, is the only factor that can have brought about the coeval deepening of the watercourses. This deepening, in fact, was not controlled by prior geodynamic activity (indeed, it starts from a subhorizontal surface), nor by base level variations downstream of the Asti Reliefs (these have been demarcated downstream by a flatland). The relief energy of the Asti Reliefs, therefore, expresses in a clearly legible manner, purely the mobility which occurred during their modelling.

The general, primarily vertical, erosion process was repeatedly interrupted by lateral erosion episodes, at times followed by sedimentation. These veneers of deposits preserved at various levels on the terraced series, are made of loam and were deposited by overbank floods.Therefore these, geologically, correspond to nearly istantaneous sedimentation episodes. Despite their reduced thickness, these deposits are of fundamental importance since, as mentioned earlier, they are the only feature on which a chronological interpretation can be attempted.

The difference in uplift led to a series of changes in the hierarchy of the evolving drainage system. It is also responsible for the lateral migration of some watercourses, resulting in asymmetry of the transverse profile of many valleys and in the systematic decapitation of some branches of the stream network. What is now the very steep right flank of the Tanaro, for example, is clearly decapitating the system of left-hand affluents of the adjacent basins to the SE (see Fig. 3).

Differential uplift in the Asti Reliefs area can be demonstrated from the profile in Fig. 10 [1]. In this figure, each solid lines corresponds to a rectified longitudinal profile of a temporary bed of Tanaro river. This W-E section shows the existence of gentle slopes lying roughly N-S or, in any case, transversely to the approximately W-E axis of the main deformation movement.

The "counter-slopes" in the longitudinal profiles of the Borbore terraces (Fig. 10 [2]) evidence the deformation that took place after the surfaces themselves (A, B1 and B2) were modelled. These "counter-slopes", of course, are but the deformation component of opposite sign compared with the original very low gradient of the reference surface. Therefore, the total altitude difference in the longitudinal profiles starting from Unit 1, corresponds to the vertical component, necessarily underestimated, of the deformation that took place between the shaping of the Unit 1 and the Holocene. It has been seen, in fact, that this surface originally corresponded to a single fluvial erosion-plain with a very slight eastward dip. Deepening of its watercourses must have been solely brought about by its uplifting. In view of the considerable inertia of the ratio between uplifting and erosion, however, it cannot be supposed that this had been fully compensated before the trend was reversed during the course of the Holocene.

Turning now to quantities, it is important to note that the extent of the deformation of the Complex A deposits, as far as it can be deduced from the profile mentioned, is fully comparable with that of the Unit B1.

By contrast, the basal surface of the B2 deposits is deformed to a much lower degree. These data indicate that deformation of the basal surfaces of the Complex A and of the Unit B1, obviously took place only after their deposition, but mostly before the deposition of B2, *i.e.* between the end of the Middle Pleistocene and the beginning of the Upper Pleistocene (see § 6).

This evolution pattern underwent a brusque change very close to the Present. The marked variations in the morphological picture that occurred during the Holocene, mark the birth and rapid growth of a structure that brought about the separation of the Poirino Tableland from the Asti Reliefs. The latter sank to an extent that their summits are now, on the average, lower than the Tableland. The onset of the "Marginal flexure of the Poirino Tableland", which lies N-S in this segment, but becomes NE-SW in the more Southern section (see Carraro *et al.*, 1982), marked a new watershed line and resulted in two important changes in the stream network pattern. The collector of the Southern Piedmontese basin, which immediately prior to this event flowed from West to East via the Poirino Tableland, the Asti Reliefs and the Alessandria Plain, was diverted into the section lying between Santena and Turin, and acquired the present course (River Po) to the North of the Turin and Monferrato Hills. The local Banna network was subsequently developed on the Tableland. Its flow direction is opposite to the previous one (Forno, 1982) and in several

Fig. 10 - Longitudinal rectified profiles of the U.M. linked to Tanaro River (for explication, see text); 2) Longitudinal rectified profiles of the U.M. linked to Borbore River (for explication, see text).

1) Profili longitudinali rettificati delle Unità di modellamento legate al F. Tanaro (per la spiegazione si veda il testo); 2) Profili longitudinali rettificati delle Unità di modellamento legate al F. Borbore (per la spiegazione si veda il testo).

places it makes use of abandoned channel segments. A local system also came into being in the Asti Reliefs. This exploits (with no change in flow direction) the incisions of the previous larger net.

The Tanaro until then was a right-hand affluent of the "collector of the Southern Piedmontese basin", both when it flowed South of the Turin and Monferrato Hills, and after its diversion. A short time later, itself overflowed at roughly the point were the town of Bra now stands. For this purpose it used the valley of a right-hand affluent of the "collector of the Southern Piedmontese basin" (Castiglioni, 1979). This phenomenon was the consequence of the growth of the "Poirino Tableland marginal flexure", the evolution of which was and still is very rapid. For this reason there is a substantial spatial coincidence between the structure and its morphological expression. It has already been stated that B. Castiglioni drew attention to virtual absence of wearback displayed by this singular scarp, whereas it bears very evident signs of accelerated erosion.

The scarcity of the data available, and above all the low definition of the chronological references, greatly restricts the quantitative evaluation of mobility. Moreover, it is clear that the deformation which has been recognised is the greatest but not the only one which affected the studied area.

The vagueness of the reconstruction of the evolution derived from the several factors mentioned concerns also the moment-by-moment configuration taken on by the stream network. In the specific case, features preventing an unequivocal interpretation are forms (saddles, counter-slopes on valley flanks) that may be traces of previous stream configurations, but could be also due to differential erosion(15).

Despite these limitations, the main stages in the evolution of the pattern of the stream network can be assessed (Fig. 9). The data shown on the morphostratigraphic map (Fig. 7) were used to figure out the relief at its various modelling stages, spanning from the Middle Pleistocene to the Present.

The limitations of this representation are far from negligible. They are due to the inevitable interpolations on several sections, even if based on purely geometrical data.

It follows that the configurations are conditioned by a degree of uncertainty varying from one case to another. This degree of uncertainty decreases as the present configuration is approached on account of the progressively better preservation of the morphological features.

It also relates to the details of the configuration and not to its essential features (pattern and flow direction of the various collectors), which can be regarded as satisfactorily established. In the central sector of the area the main collector flowed W-E, *(i.e.* along the relative lowering axis from the moment of its establishment on the erosion-plain, during the Late Lower Pleistocene).

This pattern is preserved in the stretch of the Tanaro between Asti and Alessandria, in a short length of the Borbore immediately upstream from its confluence with the Tanaro and in a section of the Triversa between Villafranca and Baldichieri. These can be regarded as true relics inherited from the original pattern of the stream system.

During the same time period (Late Lower Pleistocene), there was a second collector of much the same size in the Northern sector. It, too, ran to the South of the watershed line, between the stream net of the hills to the South, and that of the Po area to the North. This drainage channel ran about WSW-ENE in its upper stretch (as far as the present town of Frinco) and continued roughly W-E (Fig. 9 [1]). This pattern has been partly inherited from the present Versa, which flows between Colcavagno and Frinco. Renewed uplifting during the Middle and Upper Pleistocene raised the sectors at the Eastern and Southern boundaries of the area, causing the deepening of the drainage branches and the onset of a different hierarchic pattern(16). In the central sector, however, along the main axis of relative lowering, running roughly WNW-ESE, the lowering continued. The main collector was still present and wore its way, even if weakly, into the substrate (Fig. 9 [1-2]) which evidences an absolute uplift, *i.e.* the area that underwent relative lowering, by comparison with its surrounding sectors, in reality is part of an absolute uplifting.

This trend has been maintained until the Present (Fig. 9 [3-4]).

To summarize, the evolution of the Asti Reliefs since the Middle Pleistocene has been marked by a generally slight differential uplifting, resulting in mild longitudinal as well as transverse warpings. These, however, have had a striking morphological effect: in particular, they are profoundly influenced by the evolution of the stream net in relation to the very gentle gradients involved.

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(15) These uncertainties, unlike those mentioned earlier, cannot be lessened by the acquisition of new data.

(16) In the northern sector in particular there was a diversion of the northern collector. This started from the position of the present village of Frinco and ran N-S until it flowed into the main collector established in the central sector of the area.

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