Bulletin de la Société belge de Géologie, T. 102 (1-2), 1993, pp. 231-241.
Bulletin van de Belgische Vereniging voor Geologie. Ed. 1994

PHILOSOPHY AND METHODOLOGY OF THE NEW GEOLOGICAL MAP OF THE TERTIARY FORMATIONS, NORTHWEST FLANDERS, BELGIUM

by

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ABSTRACT

The most recent detailed geological map of Belgium (scale 1:40000) dates from the turning of the century. The Belgian Geological Survey and the Directorate of Natural Resources and Energy of the Flemish Ministry of Economic Affairs commissioned a new geological map (scale 1:50000) to the Geological Institutes of the Universities of Gent and Leuven, to be drawn on basis of the archives of the Geological Survey, completed with data provided by licentiate and Ph.D. theses, publications, internal reports,...

As it was the commissioners' aim the new geological map to have a greater applicability and to be highly user friendly, the option was taken to adopt lithostratigraphical units as the basal mapping units, enabling secondary economical and planning survey derivations, illustrating the map's more thematical character.
All data (identifications, coordinates, characteristics, descriptions, interpretations, corrections) are stored in d-base4 tables (PC environment with MS-DOS). Maps of the top Tertiary topography outcropping under the Quaternary cover can be drawn, together with contour maps of the boundary surfaces of all occurring lithostratigraphical units.
For the present, the new geological maps of the Brugge (13) and Lokeren (14) sheets are completed at the University of Gent on basis of the intersections of the Tertiary litho unit boundary surfaces with the top Tertiary topography. Lateral facies changes within litho units or problematical lateral extensions will be elucidated by additional drilling. Software data treatment allows cross section construction, derivation of litho unit architecture data (isopach maps,...) and 3D surface models or boundary surfaces. Explanatory text of the Brugge (13) sheet provides information of general interest, Quaternary history, subsoil geology,... next to litho unit description, map legend, maps, methodology, excursion route, natural resources,... Publication of both map and text of the Brugge sheet is end 1993.

KEY WORDS

Geological map, philosophy, methodology, Tertiary, Northwest Fanders.

RESUME

La carte géologique détaillée de la Belgique la plus récente (à l'échelle du 1:40000) date de la fin du siècle passé et du début de ce siècle. Le Service Géologique de Belgique et la Direction des Ressources Naturelles et de l'Energie du Ministère Flamand d'Economie ont demandé aux Instituts Géologiques des Universités de Gent et de Leuven d'établir une nouvelle carte géologique (à l'échelle du 1:50000) sur base des archives du Service Géologique complétées des données des thèses de licence, de doctorat, ainsi que des publications, mémoires internes, ...
Vu l'importance que les promoteurs du projet attachaient à une plus grande utilisation de la carte ainsi qu'à sa meilleure application, ceux-ci ont pris pour option d'adopter des unités lithostratigraphiques pour base des unités cartographiables,

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permettant par après, son usage dans un cadre économique ou d'aménagement du territoire qui de plus offrait également la possibilité d'illustrer le caractère thématique de la carte.
Des tableaux récapitulatifs de données (identifications, coordonnées, caractéristiques, descriptions, interprétations, corrections) ont été établis à l'aide du programme DBase4 pour PC sous MS-DOS. Des cartes de topographie du sommet du Tertiaire affleurant sous le Quaternaire, peuvent être dessinées en même temps avec les contours des limites de formation pour toutes les unités lithostratigraphiques.
Actuellement, les nouvelles cartes géologiques pour les planchettes de Brugge (13) et Lokeren (14) doivent être complétées à l'Université de Gent sur base des limites des unités lithostratigraphiques du Tertiaire avec la topographie du sommet du Tertiaire. Des variations latérales de faciès dans les unités lithostratigraphiques ainsi que les problèmes d'extensions latérales pourront être éclaircis grâce à des forages supplémentaires.
Le traitement des données informatiques permet l'élaboration de coupes, la délimitation des unités lithostratigraphiques (cartes d'isopaches, ...) ainsi que l'établissement de modèles tri-dimensionels des surfaces topographiques ou des plans de limite. Le texte explicatif de la planchette de Brugge (13) contient des éléments d'information générale, un historique du Quaternaire, de la géologie profonde ainsi que la description des unités lithostratigraphiques, la légende de la carte, la carte géologique elle-même, un descriptif d'excursion, des données sur les ressources naturelles, ... Fin 1993, vient d'être publié la carte ainsi que le texte explicatif de la planchette de Brugge.

MOTS CLES

Carte géologique, philosophie, méthodologie, Tertiaire, partie nord-ouest de la Flandre.

1. INTRODUCTION

The most recent official geological map of Belgium (1:40000) (fig. 1) dates from the turning of the century and provided mainly information on sediment body presence and age as representative indications of "space" and "time" in geology. But the general use of the map for non-professional geologists was rather limited due to the more (bio)stratigraphical character of map legend and stratigraphical column.
The new geological map puts more emphasis on lithology (clay, sand, gravel,...), content (fossils, sandstone layers,...) and boundary surfaces (nature, lower and upper,...) of the sediment bodies. The introduction of the "mappable unit" as the basic philosophy for the map adds to space and time as basic concepts a "facies" connotation. The old geological map groups sediment bodies (or layers) with more or less the same age, but not necessarily the same lithology (clay, sand, gravel, peat,...) which can vary considerably within the same unit, thus hampering the use of the old map by non-professionals. The legend sometimes groups "sand, clay, loam" or other facies within one single unit especially of Quaternary age (table 1).
As the last map dates from about 100 years ago, observation points disappeared and new ones became available; ideas evolved as did geological observation techniques. In the past only direct observations (quarries, outcrops, wells) were possible, while for the moment all sorts of indirect observation techniques quantify and use sediment body geophysical properties as a stratigraphical tool.

2. PHILOSOPHY OF THE NEW GEOLOGICAL MAP

For all this reasons a revision of the geological map became necessary. The commissioners (the Belgian Geological Survey (BGS) of the Ministry of Economic Affairs and the Directorate of Natural Resources and Energy (DNRE) of the Administration of Economy of the Flemish Ministry) also decided to put more emphasis on the utility of the map and on the accessibility of the data, necessitating a redefinition of the mapping philosophy. Next to "space and time", attention should be paid to "facies" of the litho units. Next to age ("time") and presence ("space"), facies, nature of (upper and lower) boundary surfaces or other characteristics visible in the field should be taken into account. "Mappable units" should be introduced as basic philosophy in the cartography of the new geological map. Each sediment body with constant characteristics and facies of a lateral extend decernable on a map, forms a "mappable unit". Whether this unit will be represented on the map or not, depends from the map scale. In general the identification of the litho units in the field plays a much greater role as mapping criteria rely much more on the lithology of the deposits. Sand facies will be differentiated from clay facies and therefore be represented on the map as a separate unit if the map scale is appropriate. The stratigraphical column is much more lithology inspired (table 2).
The BGS and DNRE commissioners asked for the separate mappability and mapping of sediment bodies or litho units differentiated in the field. In reality this coincides with the reconstruction of the areal extend

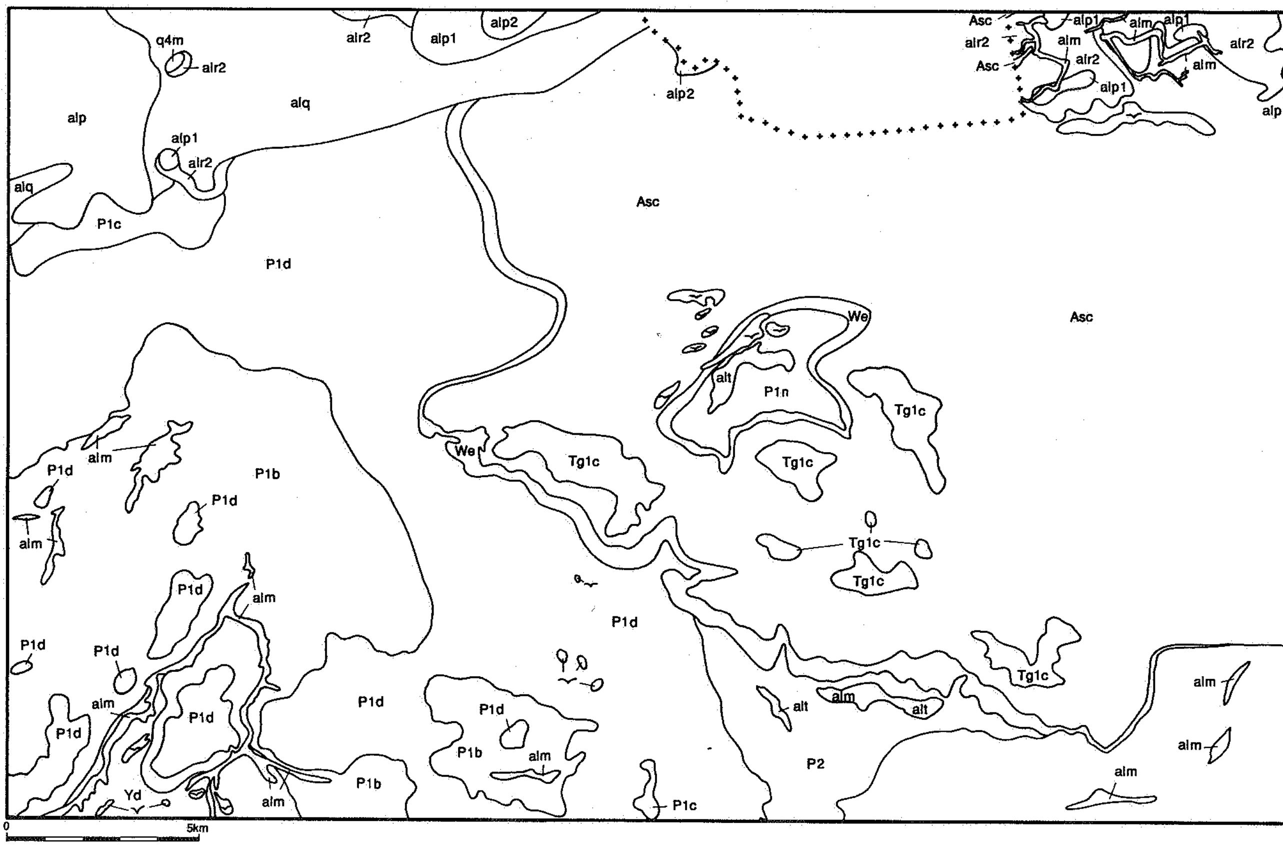

Figure 1. Old geological map (1/40000) of the Brugge sheet (13).

(architecture) of the different sediment bodies, made to user's demand. This implicates as technical requirements for the new geological map a great flexibility of map scaling, high data resolution (many data of good quality in a restricted area) and easy manipulation of the database.
The principles of "mappability" and "restauration of the lithology concept" in cartography should also be found back in the methodology of the database organization and in the map drawing.

3. METHODOLOGY OF THE DATABASE ORGANIZATION AND OF THE MAP DRAWING

An important step in the drawing of a geological map is the collection and the storage of all information available. All data from the BGS archives were completed with the archives of the Geological Institutes of the Universities of Gent and Leuven, consisting mainly in lithological and stratigraphical descriptions of wells and geophysical well logs. Also data provided by drillings and geotechnical (mostly cone penetration) tests from the archives of the State Institute for Geotechnics (now Directorate for Geotechnics of the Flemish Ministry) have been added to the database. Further use has been made of university (licentiate and Ph.D.) theses, publications, public domain reports of geological surveys,...
To store all data orderly and efficiently, preference has been given to a computerized database instead of a manual file system. A PC configuration environment with MS-DOS offers a lot of possibilities, became common use and is very user friendly. Consultation of the database will be possible in the near future at the Belgian Geological Survey and at the Directorate of Natural Resources and Energy of the Flemish Ministry. The database has been organized in modules of d-base4 tables because of their relatively easy use. Software programmes enable information consult in the tables, borehole description reconstruction,...

The database is composed of following tables:

- a table with standing information on each observation point (table 3): identification number, topographical information, observation characteristics (nature, drilling technique, depth,...) and reliability identifications
- three tables with data on the smallest litho unit identified for each observation point (individualizing a deposit!) :
  - depth level of top and thickness of the litho unit
  - lithological description
  - stratigraphical interpretation

GROUPE QUATERNAIRE

SYSTEME QUATERNAIRE SUPERIEUR OU MODERNE

ale	Alluvion des pentes.
alp2	Argile des polders supérieure.
alq	Sable meuble à *Cardiums* avec linéoles argileuses vers le haut, parfois lit tourbeux et graveleux à la base.
alp1	Argile des polders inférieure.
alr2	Alternances de sable gris et d'argile sableuse gris foncé.
t	Tourbe.

SYSTEME QUATERNAIRE INFERIEUR OU DILUVIEN

FLANDRIEN (q4)

q4	*Facies normal.* Sable jaune, meuble, avec, parfois, une linéole tourbeuse et un lit graveleux à la base.
q4m	*Facies marin.* Sable gris verdâtre, meuble, parfois limoneux, avec coquilles marines, surtout vers la base.
q4l	Zones limoneuses, grises, intercalées dans q4m.

HESBAYEN (q3)

q3m	Limon gris avec linéoles sableuses, passant au sable vers le bas. Coquilles terrestres.
t	Tourbe.

CAMPINIEN (q2)

q2m	Argile grise plastique, sable grossier, meuble blanc avec cailloux roulés à la base.

GROUPE TERTIAIRE

SYSTEME EOCENE

EOCENE SUPERIEUR

ETAGE ASSCHIEN (As)

Asc	Argile glauconifère et argile grise.
Asb	Sable argileux glauconifère.

ETAGE WEMMELIEN (We)

We	Sable à *Nummulites wemmelensis*; gravier à la base.

EOCENE INFERIEUR

ETAGE PANISELIEN (P)

ASSISE INFERIEURE (P1)

P1d	Sable meuble, glauconifère avec concrétions gréseuses.
P1c	Sable argileux glauconifère, avec concrétions gréseuses.
P1b	Sable grossier, meuble, avec gros points de glauconie, grandes paillettes de mica blanc et fragments noirs de lignite xyloïde; parfois, concrétions gréseuses.

ETAGE YPRESIEN (Y)

Yd	Sable fin, gris foncé, un peu coherent, avec paillettes de mica et nombreux spicules de spongiaires.
Yc	Argile grise.

Table 1. Stratigraphical column of the old geological map of the Brugge sheet (13) (partim).

- a table with the geophysical parameters (grain size, resistivity, geotechnical properties,...).

All available information relevant to the observation point is stored into the database. Special attention is paid to the information reliability. Lithological descriptions of cored wells are much more reliable than those of flushed wells due to sediment mixing; therefore depth of samples and of boundary surfaces can not

Ma Maldegem Formation (Middle and Upper Eocene)

MaOd	**Onderdijke Member** Grey blue stiff clay, non calcareous, 6 to 10m thick.
MaBu	**Buisputten Member** Dark grey medium fine sand, glauconitic and micaceous, 6 to 7m thick.
MaZo	**Zomergem Member** Grey blue clay to stiff clay, non glauconitic, non calcareous, 6 to 8m thick.
MaOn	**Onderdale Member** Dark grey, medium fine sand, glauconitic and micaceous, 2 to 4m thick.
MaUr	**Ursel Member** Grey blue to blue, homogeneous clay, slightly or non calcareous and non glauconitic, 12 to 13m thick.
MaAs	**Asse Member** Strongly glauconitic sandy clay, upwards gradually transitioning into the Ursel Member; locally, especially at the base, with coarse glauconitic sand ("bande noire"), 2 to 4m thick.
MaWe	**Wemmel Member** Grey glauconitic fine sand, more clayey towards the top; basel zone with *Nummulites wemmelensis*; 4 to 5m thick.

Aa Aalter Formation (Middle Eocene)

AaOe	**Oedelem Member** Light grey medium fine to fine sand, fossiliferous at the top, much less at the base; sometimes with three calcareous sandstone layers; especially around Aalter very fossiliferous (*Venericardia planicosta*), 10 to 18m thick.
AaBe	**Beernem Member** Grey green glauconitic and micaceous, slightly calcareous clayey sand, with thin clay layers and sandstones; up to 8m thick; only occurring in the western part of the map (Brugge, Loppem, Beernem).

Ge Gent Formation (Lower Eocene)

GeVl	**Vlierzele Member** Grey green glauconitic fine sand, with distinct horizontal or cross bedded layering, with clay lenses; thin humic layers at the top, locally with thin sandstone layers, at the base transitioning into a homogeneous clayey very fine sand; thickness strongly variable, sometimes up to more than 20m.
GePi	**Pittem Member** Glauconitic clayey very fine sand, alternating with sandy clay, locally with sandstone layers very rich in fossil moulds; thickness strongly variable, up to 15 or 20m.
GeMe	**Merelbeke Member** Dark grey clay, thin sand lenses with organic material and pyritic concretions, thickness variable up to 6 or 7m.

Tl Tielt Formation (Lower Eocene)

TtEg	**Egem Member** Micaceous and glauconitic very fine sand, with distinct horizontal or cross bedded layering, alternating with thin clay layers; up to 20m thick.

Table 2. Stratigraphical column of the new geological map (1:50000) of the Brugge sheet (13).

Table 3. Table with standing data of an observation point with lithostratigraphical description of the different sediment bodies.

KAARTBLAD : 40W
BORING NUMMER : BGD 18 INTERN_NR:
X-KOORDINAAT : 104.9500 DIEPTE : 67.00 m
Y-KOORDINAAT : 198.4800 BOORFIRMA : Delecourt
HOOGTE MAAIVELD : 6.00 m TAW METHODE : droog
DATUM : 1929 AARD : filterput
AUTEUR OORSPR. BESCHRIJVING : Halet F.
AUTEUR OORSPR. INTERPRETATIE : Halet F. bgdnr:

beschrijving boring :

6.00 -	2.00	Q oude int : Q
0.00 -	4.00	klaargrijs, licht kwartsachtig zand
2.00 -	-5.00	Q oude int : Q
4.00 -	11.00	zeer zandige, licht kalkhoudende, fijne leem
-5.00 -	-6.00	Q oude int : Q
11.00 -	12.00	grijze, kalkhoudende leem
-6.00 -	-7.00	Q oude int : Q
12.00 -	13.00	grijs, weinig leemhoudend zand met stukken Cardium
-7.00 -	-8.00	Q oude int : Q
13.00 -	14.00	grijs, licht leemhoudend zand
-8.00 -	-9.00	Q oude int : Q
14.00 -	15.00	grijs, zeer kwartsachtig zand met een grote gerolde zandsteenkei en stukken van gebroken schelpen
-9.00 -	-10.00	Q oude int : Q
15.00 -	16.00	grijs, kwartsachtig zand met stukken Cardium edule
-10.00 -	-13.00	Q oude int : Q
16.00 -	19.00	grindachtig zand met rolkeien en stukken van schelpen Cardium edule
-13.00 -	-14.00	Q oude int : Q
19.00 -	20.00	grijs, glauconiethoudend zand met vele Ditrupa
-14.00 -	-15.00	AAOE oude int : P2
20.00 -	21.00	groenachtig, glauconiethoudend zand met vele stukken van schelpen
-15.00 -	-16.00	AAOE oude int : P2
21.00 -	22.00	opeenstapeling van stukken schelpen Cardita, Cardium
-16.00 -	-20.00	AAOE oude int : P2
22.00 -	26.00	grijs-groenachtig, kwartsachtig zand met stukken van schelpen (Turritella's)
-20.00 -	-21.00	GEVL oude int : P2
26.00 -	27.00	grijs-groenachtig, kwartsachtig zand
-21.00 -	-22.00	GEVL oude int : P2
27.00 -	28.00	grijs-groenachtig, kwartsachtig zand met zeldzame schelpen
-22.00 -	-27.00	GEVL oude int : P2
28.00 -	33.00	grijs, kwartsachtig zand met stukken bruinkool
-27.00 -	-28.00	GEVL oude int : P2
33.00 -	34.00	grijs, kwartsachtig zand
-28.00 -	-29.00	GEVL oude int : P2
34.00 -	35.00	grijs, kwartsachtig zand, licht gespikkeld, met sporen van zandsteen
-29.00 -	-30.00	GEVL oude int : P2
35.00 -	36.00	grijs, licht kwartsachtig, glauconiethoudend zand
-30.00 -	-31.00	GEVL oude int : P2
36.00 -	37.00	grijs, glauconiethoudend zand
-31.00 -	-32.00	GEVL oude int : P2
37.00 -	38.00	grijs-groenachtig, glauconiethoudend zand
-32.00 -	-36.00	GEVL oude int : P2
38.00 -	42.00	grijs-groenachtig, licht kwarstachtig, glauconiethoudend zand
-36.00 -	-41.00	GEPI oude int : P1
42.00 -	47.00	grijze, zandige klei
-41.00 -	-44.00	GEPI oude int : P1
47.00 -	50.00	zandige klei met stukken grijze zandsteen
-44.00 -	-46.00	GEPI oude int : P1
50.00 -	52.00	grijze, zandige klei
-46.00 -	-48.00	GEPI oude int : P1
52.00 -	54.00	grijze, zandhoudende klei met zandstenen
-48.00 -	-51.00	GEMR oude int : P1
54.00 -	57.00	grijze, tamelijk plastische klei
-51.00 -	-52.00	TLEG oude int : Y
57.00 -	58.00	grijs-groenachtig, weinig kleihoudend zand
-52.00 -	-54.00	TLEG oude int : Y
58.00 -	60.00	zandhoudende klei met Nummulites planulatus
-54.00 -	-55.00	TLEG oude int : Y
60.00 -	61.00	weinig kleihoudend zand
-55.00 -	-56.00	TLEG oude int : Y
61.00 -	62.00	kleihoudend zand
-56.00 -	-61.00	TLEG oude int : Y
62.00 -	67.00	grijs-groenachtig, kleihoudend zand met Nummulites planulatus

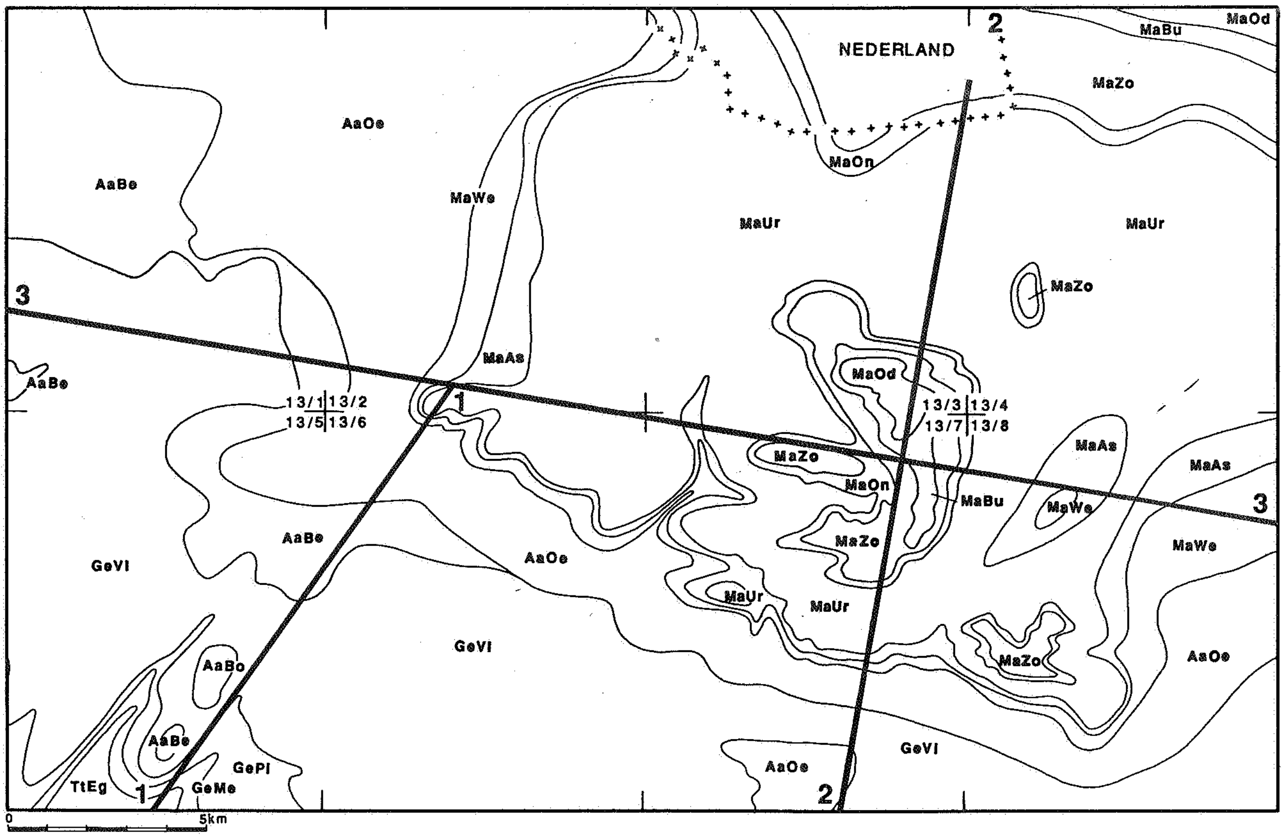

Figure 2. New geological map (1:50000) of the Brugge sheet (13) with cross section location (1-1, 2-2, 3-3).

always be positioned with accuracy. Data with a low reliability index should be handled with care if used for mapping.
After database storage, lithology and location of every observation point are compared with the original files. The stratigraphical interpretation is matched to the most recent and current criteria and adapted if necessary. All this data (corrections included) are added to the database.

After the stratigraphical data interpretation, the thickness of the Quaternary deposits in the different observation points is known, as is the Quaternary-Tertiary boundary level at which the Tertiary sediments are recorded for the first time. Isohypses interconnect points with the same elevation on the top Tertiary topography depicting its relief.
For every observation point the levels of the upper and lower boundary surface of every lithostratigraphical unit are determined. The upper boundary surface of the unit first observed under the Quaternary cover might be absent and the lower surface of the last observed unit might be missing.The upper boundary surface of a unit coincides with the lower one of the overlying (younger) unit. All levels of the lower surface of each differentiated litho unit are represented on a map with an adequate scale. Isohypses interconnect points where the same litho unit is present at the same elevation. The isohypse (or contour line) map thus describes the nature of the lower boundary surface of the unit.
The isohypse maps of the top Tertiary topography and of the lower boundary surface of the different lithostratigraphical units form the basal documents for the new geological map.The interconnection line of all intersection points between the boundary surface contour lines with the corresponding contour lines of the top Tertiary topography defines the geological boundaries. During this procedure all information concerning all observation points is constantly evaluated, its reliability checked and its stratigraphical interpretation adapted if necessary.

4. THE NEW GEOLOGICAL MAP AND ITS DERIVATED MAPS

For the new geological map emphasis is put on the modular organization of the database, enabling both description of the different sediment bodies (direct observation) and input of geophysical parameter data (geotechnical resistance, resistivity, particle size,...) provided by indirect observations. Therefore every (geo)physical parameter can be used as a mapping element or criterion. This data organization enables easy manipulation by means of software packages.

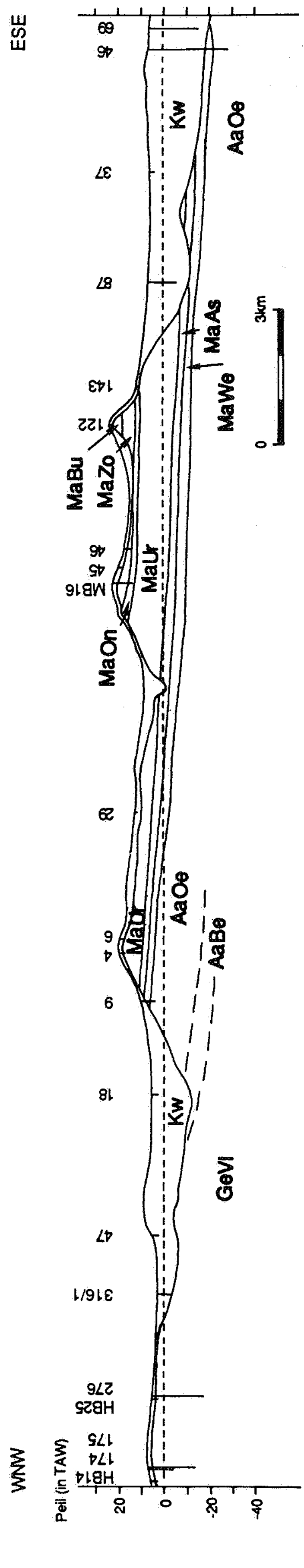

Figure 3. Cross section (3-3) through the Brugge sheet (13).

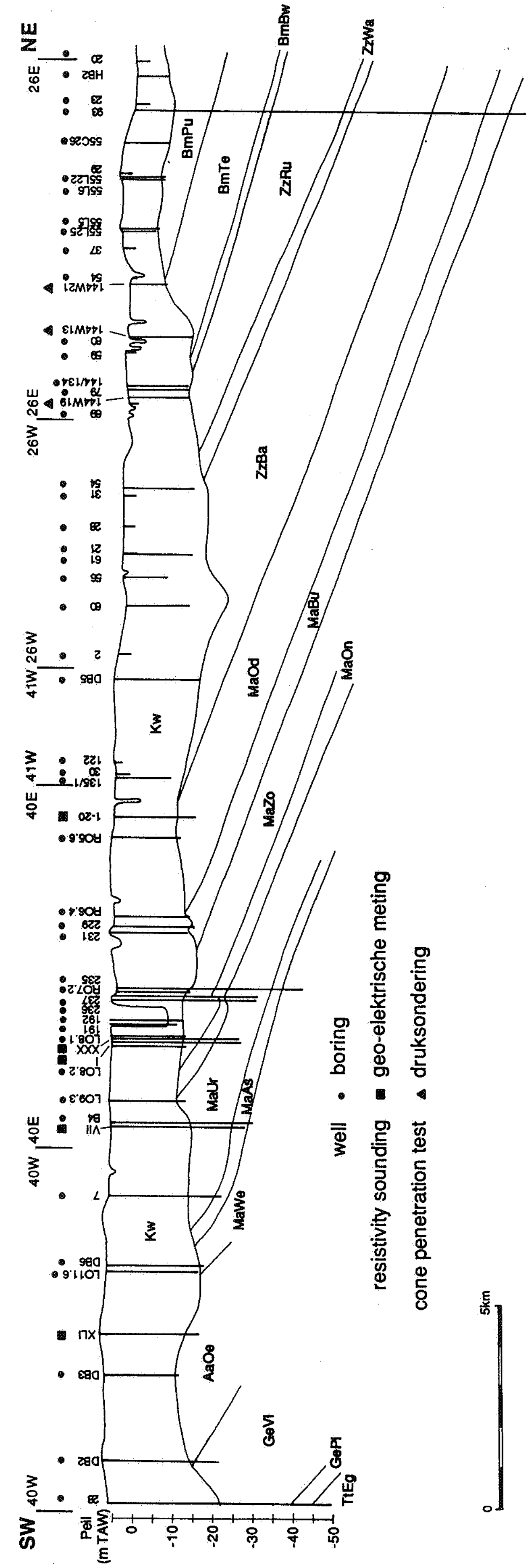

Figure 4. Cross section with geophysical parameter data from indirect observation techniques through the Lokeren sheet (14).

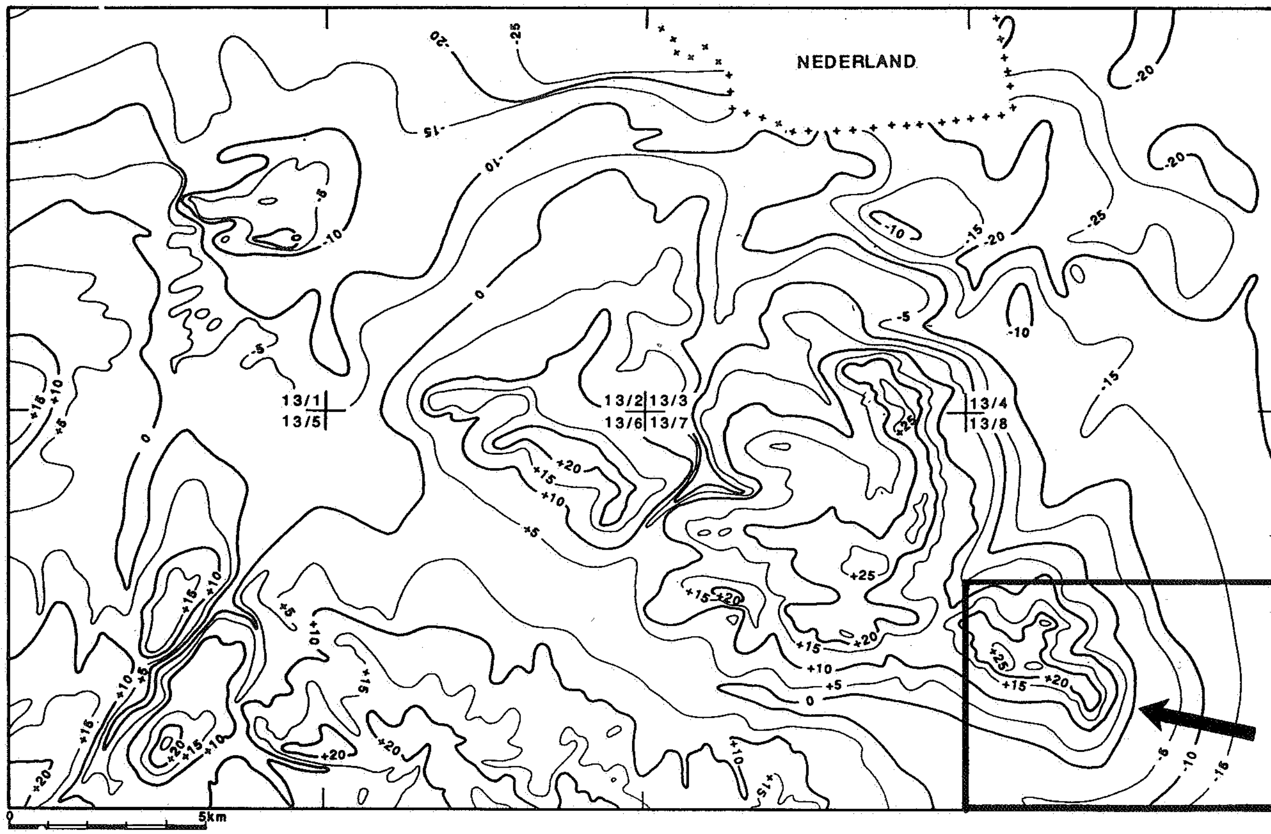

Figure 5. Isohypse map of the Tertiary topography on the Brugge sheet (13) (contour lines in m above or below sea level with 5 m equidistance). Rectangle shows location of fig. 9 (Zomergem area) ; arrow indicates angle of view.

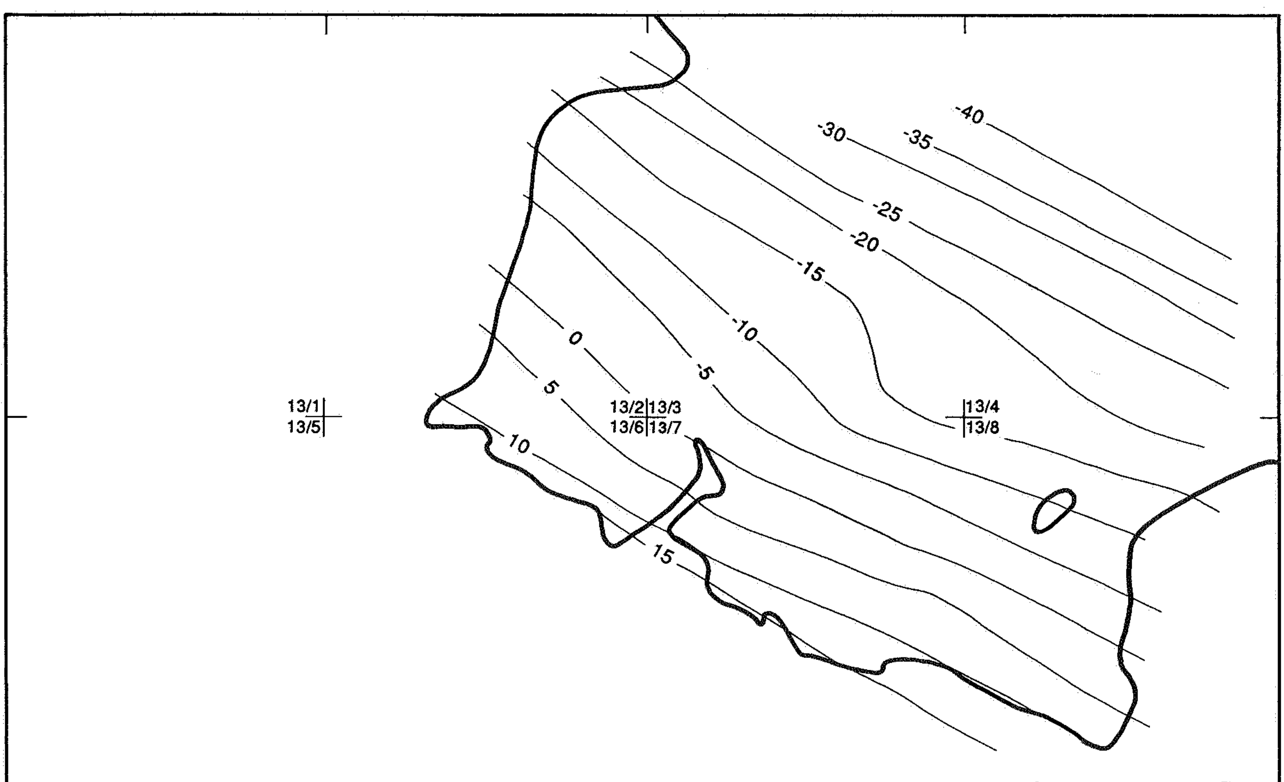

Figure 6. Isohypse map of the lower boundary surface of the Asse Member on the Brugge sheet (13) (contour lines in m above or below sea level with 5 m equidistance).

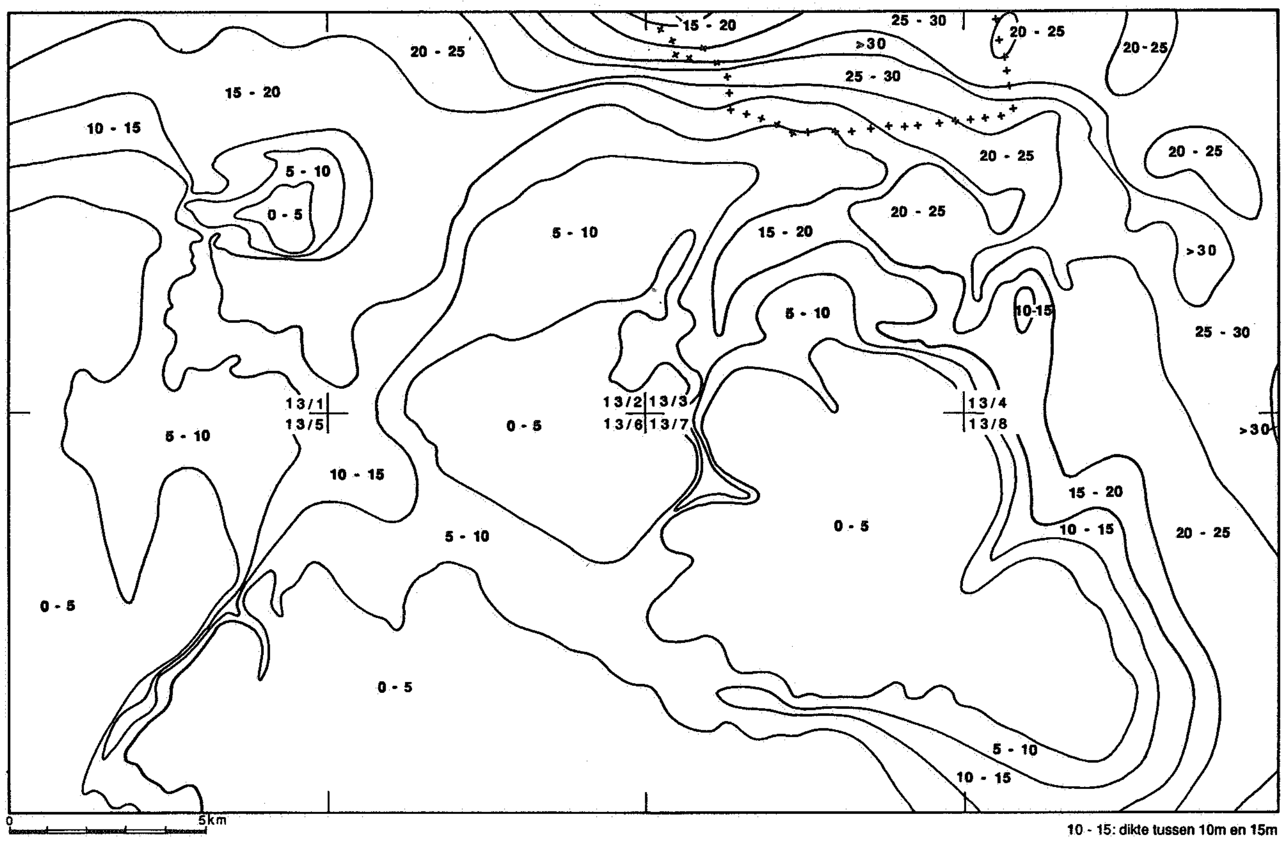

Figure 7. Isopach map of the Quaternary cover on the Brugge sheet (13) (10-15 : thickness between 10 m and 15 m).

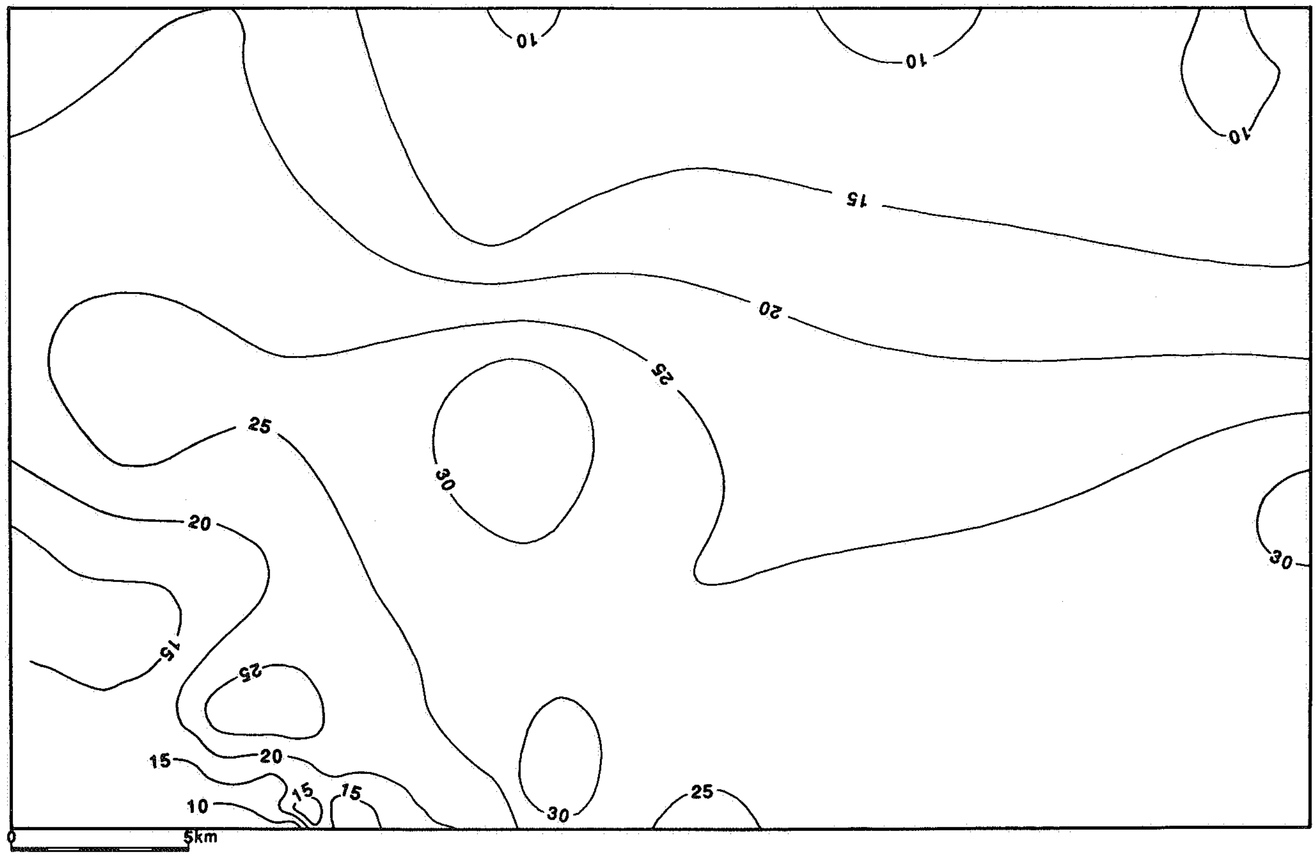

Figure 8. Isopach map of the Vlierzele Member on the Lokeren sheet (14) (---25--- : isopach contour line of 25 m thickness).

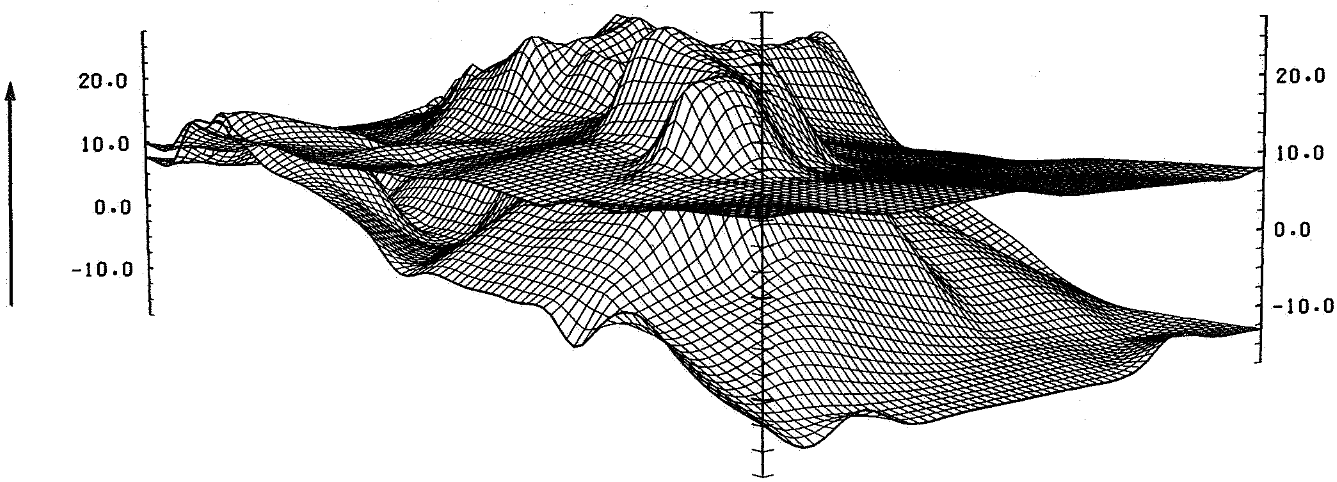

Figure 9. Three dimensional model of the Quaternary cover thickness and of the Top Tertiary topography in the Zomergem area on the Brugge sheet (13) (M. Verschuren) (10.0 : elevation in m above or below sea level).

The first result is the geological map of the Tertiary formations (fig. 2), representing the occurrence of the Tertiary deposits in Northwest Flanders. Being drawn on basis of litho units (formation, member) as mappable units, the map has therefore a lithostratigraphical character for which the new lithostratigraphical subdivision of the Palaeogene was used. In function of new insights in the chronostratigraphical position of these litho units, slight modifications might be envisaged as members are ranked in another formation or if new formation names are to be introduced.
In contrast to the old geological map the Quaternary is omitted, but all data concerning these deposits are stored in the database. Cross sections (fig. 3) illustrate the geological setting. Different directions provide insight in the areal extent of the deposits. The insertion of technical characteristics (fig. 4) visualize geophysical parameter variations within the unit under consideration.

Derivated maps depict the spatial characteristics of the deposits. Boundary surface contour lines of a unit depict the (ir)regular nature of this surface. The top Tertiary topography (fig. 5) in fact represents the topography of the erosion surface after Quaternary incision. Lower boundary surface contour maps (fig. 6) provide information on the depositional environment of a sediment package, provided all litho units concerned are of the same (chronostratigraphical) age.
If the base level is subtracted from the top level of a unit, the unit thickness is obtained. Isopach maps indicate the areal distribution of the unit thickness under consideration, while isopach contour lines interconnect points with the same unit thickness. Isopach maps in fact result from the subtraction of the isohypse maps of the upper and lower boundary surface. Isopach maps of the Quaternary cover (fig. 7) and of the Tertiary formations (fig. 8) provide respectively information on the Quaternary history (incision of a valley and consequent infill) and shift of Tertiary depo centres in case of isochronous litho units.
Three dimensional models visually suggest the areal extent of a sediment body. Joint representation of the actual topography and of the top Tertiary topography (fig. 9) shows the three dimensional distribution of the Quaternary cover thickness. Joint representation of upper and lower sediment body boundary surfaces display sediment architecture.
The map information provided can be adapted according to the needs. If sufficient data are available, a large scale might be handled. If data resolution is very low, a small scale will be required. The detail of the map is thus determined by its data resolution.
In addition to the geological map and its derivated maps, the database itself at the BGS and DNRE forms a third important factor in the information provided. Due to easy data accessibility as a result of informatization, due to its greater user friendliness and its modular organization, the database provides nearly unlimited possibilities of data consult and combination. Lithological descriptions of well defined rock units can be combined with their geotechnical characteristics (e.g. particle size with resistivity) to correlation maps between different factors or criteria. More accurate information about the areal distribution of the sediment bodies and their characteristics is guaranteed. The new geological map as a result possesses a more lithological or "facies" character than the old map which had a more (bio)stratigraphical or "time" character.

5. CONCLUSION

The use of the "mappability" concept as the basic philosophy for the new map and the extended database (descriptions, age, content, boundary surfaces, geophysical characteristics) will make the new map much more user friendly. Like the archives formed the database for the old geological map, the "geological information system" forms the computerized database for the new map. The modular organisation of the database enables quantification through data input provided by geotechnics, (hydro)geochemistry, hydrogeology, geophysics,..., in addition to litho unit description. The easy transformation of the stored data into geological maps, isohypse or isopach maps, or two dimensional cross sections and three dimensional space networks makes the new geological map with its derivated thematical maps and database a much more accessible and useful information tool for the non-professional geologist than the old map. Data input reliability and resolution stands as the only limitation for the quality of the new map if large scales are required.

Manuscript received on 6.07.1992 and accepted for publication on 18.08.1992.