

## THE EXTENDED PERFORMANCE RANGE OF THE G3 STEREOCORD

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### 1. Introduction

The G3 Stereocord is a simple analytical plotting system for numerical and graphical plotting in photo interpretation and photogrammetry. The G3 version and its basic functions were presented in 1981 by H. Mohl /1/. In the meantime, this version has been expanded into a system tailored mainly to graphical applications by means of new hardware and software components. In view of the wide range of applications of the G3, the development work was done by experts of different fields<sup>1)</sup> in exemplary cooperation. The G3 design concept enables the user to configure the software in accordance with his specific requirements. Thus the G3 Stereocord can truly be called a universally applicable plotting system.

### 2. G3 Hardware

The G3 Stereocord consists of the following hardware components:

- Opto-mechanical viewer for viewing and measuring stereo pairs
- Direc 2 counter and interface unit
- Hewlett-Packard HP 85 or HP 86 desktop computer (Fig. 1)

The opto-mechanical viewer with  $x'$ ,  $y'$  and  $px$  components for measuring the coordinates of the left photo or the  $x$  parallax can be extended by a  $py$  component for measuring the  $y$  parallax. This version of the Stereocord can be used as a computer-supported stereo comparator.

The HP 86 computer is a high-performance personal computer which, apart from the G3, is equipped with 64 KB main memory, a 12 in. graphics CRT unit, a 5 1/4" floppy disk drive with a capacity of 270 KB, a matrix graphics printer with a printing rate of 80 characters per second and an HP IB interface. This computer can be programmed in BASIC and has a considerable growth potential. Fast access to one or several floppy disk drives speeds up processing in particular during graphical plotting. The HP 9872 C (DIN A3), HP 7580 (DIN A1) or HP 7585 (DIN A0) plotters can be used for graphical output. The high operating speed of the plotters and the choice of up to 8 different tracing tools effectively support the plotting-oriented graphical software.

The viewer and the Direc 1 of the prior G2 version can be upgraded for connection to the HP 85 or HP 86 and for processing the new software.

### 3. G3 Basic Software

The basic software of the G3 is shown in Fig. 2. It comprises programs for interior, relative and absolute orientation and programs for measuring single points, distances, angles, areas and volumes. Detailed descriptions are contained in /1/ and /2/.

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- 1) Project management: Dipl.-Phys. H.-W. Faust, Carl Zeiss, Oberkochen  
Basic programs: Prof. Dr. H. Mohl, Fachhochschule für Technik, Stuttgart  
Graphical programs: Prof. Dr. E. Jordan, Geograph. Institut TU Hannover,  
Dipl.-Ing. W. Kresse, Bonn

The orientation programs are based on an improved rigorous mathematical model that ensures sufficient precision in keeping with the instrument precision not only in planimetry (20 to 30  $\mu\text{m}$  in the photo scale) but also in elevation (0.2 % of flying height) provided the quality of the photos and the control points is adequate (see section 6.2). If the fourth component (py) is also digitized, orientation is speeded up considerably. Regarding the orientation programs, the following features may be mentioned:

- Photos of any format up to 23 cm x 23 cm.
- Random fiducial mark arrangement and focal lengths and virtually unrestricted taking configurations.
- 6 to 25 points for relative orientation and 3 to 15 points for absolute orientation.
- The control points can be read from a control point memory with a maximum capacity of about 65 points; points can be edited, deleted, modified and added.
- Parameter orientation, reading of parameters used in prior orientation operations, and measurement of fiducial marks.

After orientation, the above variables are measured, displayed, printed and stored in data files. About 5000 variable values can be stored on a separate cartridge or floppy disk. XYZ ground coordinates are used to compute variables like angles, areas or volumes. A common characteristic of the orientation and measurement programs and of the graphical software described below is operator guidance by means of menus. Explanations, instructions, results as well as correction and selection possibilities are displayed on the CRT screen (Fig. 3). The soft keys of the computer are used for menu selection.

The comprehensive capabilities of the Stereocord software are thus made available to users who are not familiar with photogrammetry in a simple way. Users who intend to develop their own application programs can use the BOSS program to integrate these programs in the G3 software. The basic programs and specific application programs (see section 5) were developed by H. Mohl.

#### 4. G3-GRAPHIC

The basic programs and the application programs described in section 5 are provided for quantitative photo interpretation tasks. Since numerical result representation is insufficient in many cases in particular in the geo sciences, a universal software package was conceived in response to a proposal made by E. Jordan and implemented for the G3 Stereocord by W. Kresse in close cooperation with E. Jordan and Zeiss /3/. This optional software package was called G3-GRAPHIC and has been used by the Geographical Institute of the Technical University of Hannover since 1982. Several projects have been processed successfully (geomorphology, glaciology, see /4/). The HP plotters mentioned in section 2 were used for mapping.

The G3-GRAPHIC software implements computer-supported direct mapping. This means that the operator selectively measures points, lines and areas for automatic on-line plotting with the connected plotter in a predefined graphical representation, i. e. the graphical information is not stored permanently as in digital mapping (see /5/). The salient features of G3-GRAPHIC are its flexibility and user-friendliness. The user can define and edit the desired graphical representation in a preparation phase and have it plotted automatically by the computer in the execution phase. There are limits to the mapping system, of course, due to the use of a relatively small computer.

G3-GRAPHIC comprises the programs shown in Fig. 4. By their functions, these programs can be assigned to three groups as follows:

1. SYMBOL program for digitizing symbol patterns and for symbol management.
2. MAP and TEXT for map preparation, lettering and legends.
3. LINE, AREA and PROFIL for plotting the map content.

The individual programs are called and controlled by the DRAW program. During normal project processing, the SYMBOL program is called first. It can digitize and manage up to 200 symbols and consists of the SYMGEN and SYMWRK segments.

SYMGEN controls digitization of the symbol pattern, which is placed on the Stereocord photo carriage instead of a photo. Straight lines, arcs and circles can be digitized. The symbols are assigned a number and a designation and stored in the symbol file (tape, cartridge). Stored symbols can be displayed on the screen, edited (deletion, rotation, sequence modification) and be used again for other projects (see Fig. 5). The SYMWRK segment was developed in response to experience gained during practical work. It allows 100 "work symbols" to be defined and managed. Not only the symbol type but also the size, rotation, spacing along lines and area distribution can be specified and stored as a work symbol under one number. During model plotting, 10 work symbols are loaded in the computer main memory for fast and easy access.

The MAP program is then called for map sheet preparation. It enables map frame and grid plotting, specifying the scale and the plotting window and, if desired, map sheet orientation for subsequent air photo plotting.

The TEXT program serves to enter symbols and their explanations in the map legend and for lettering with names etc. with optional character size, slant and rotation (see Fig. 8).

When the preparatory work is completed, the content of the oriented model can be plotted. The LINE program serves to digitize linear structures like roads, rivers or break lines and to plot them with the selected work symbols. Digitization is automatic by time increments or selective by foot switch depression. LINE also allows points and elevations to be plotted with optional symbols and characters. The AREA program serves to map plane structures like lakes, stands, buildings etc. The area is measured as a closed traverse and can be hatched or filled with symbols. So-called islands can be kept clear, and boundary lines can be plotted or omitted. Mapping and area computation can be combined. Finally, the third mapping program called PROFIL enables elevation plotting along a line with independent planimetric and elevation scales.

The many application possibilities are documented in /6/ and illustrated in Fig. 6 by means of an example (LINE flowchart). Sample applications of the G3-GRAPHIC software package are described in section 6.

## 5. Optional Application Software

The following optional application programs are available in addition to the basic programs and G3-GRAPHIC:

- (a) FORESTRY Program  
for forestry investigations, computing tree heights and crown areas, counting, and statistical analysis.
- (b) GEOLOGY Program  
for measuring slope angles, strike and dip angles of rock strata, and statistical analysis.
- (c) PLANNING Program  
for planning work inclusive of measuring and adding up individual areas, profiles, counting of objects, and statistical analysis.
- (d) TRANSFER Program  
for transferring data files between the HP 85/86 and an HP 1000 computer via the HP IB interface. TRANSFER has to be loaded in the desktop computer and in the minicomputer. It allows measured data to be transferred from the Stereocord to a general file of the HP 1000 for further processing with PAT M or HIFI, for example, or control point data to be transferred from the HP 1000 to the control point file of the Stereocord.

## 6. Applications

As described in /7/ on quantitative photo interpretation, the Stereocord has been designed for a very wide field of applications. The G3 version with its precision increase opens up the medium-precision photogrammetric plotting field, and G3-GRAPHIC opens up further photo interpretation fields. Therefore, only some examples can be given in the following.

## 6.1 Thematical Maps

The thematical mapping capabilities are illustrated in Fig. 7 by means of a geomorphological map. Stereoscopic interpretation of air photos is particularly suited to geomorphology, the science of terrain surface configurations. The available programs enable the measurement of differences in elevation, slope angles, surface areas etc. The mapping programs (LINE, AREA) serve to plot steps, edges, slopes, bottom lines or planes with different inclinations. The legend was created with the TEXT program. The elevation profile, which follows a line indicated in the map, rounds off the relief representation (Fig. 8).

## 6.2 Photogrammetric Plotting

Examples of graphical and numerical mapping are:

- Production of a scale 1:10.000 land utilization plan (Fig. 9)
- Revision of topographical maps
- Scale 1:100 facade plot from terrestrial stereograms made with the SMK 120 (Fig. 10)
- Measurement of digital terrain models using topographically selected points and lines
- Aerotriangulation of model blocks inclusive of point measurement with the Stereocord, transfer of the point data to the HP 1000 minicomputer with the TRANSFER program, and block adjustment with PAT M. The point measurement performance of the G3 Stereocord was determined by means of several test blocks. The Appenweiler block (wide angle, photo scale 1:7500, 10 models, 220 point measurements) yielded the following result:

$$\sigma_0 \text{ planimetric: } \pm 0.2 \text{ m} \hat{=} \pm 25 \text{ } \mu\text{m}$$

$$\sigma_0 \text{ elevation: } \pm 0.2 \text{ m} \hat{=} \pm 25 \text{ } \mu\text{m} \hat{=} \pm 0.2 \text{ } \%$$

These results are very good (measurement and computations: Fachhochschule für Technik, Stuttgart, and Photogrammetrisches Institut der TU Stuttgart). About 25 minutes per model are required for preparations, orientation and measurement of 6 to 12 points.

## 6.3 Training

The G3 Stereocord is an ideal state-of-the-art instrument for training students in numerical and analytical photogrammetry and in computer-controlled mapping. Major photogrammetric plotting operations such as

- stereoscopic viewing and measurement
- interactive numerical orientation
- computer-supported interactive plotting and
- computer-controlled mapping

have been solved in the G3 Stereocord in a didactically exemplary way. The PILOT program enables the user to develop his own application programs and to integrate them in the G3 software. This is the reason why, in the basic training of photogrammetrists, conventional analog instruments such as the DP1 double projector should be complemented or replaced by modern Stereocord type instruments.

## 7. Conclusions

The G3 Stereocord is an easy-to-handle universally applicable medium-precision plotting system. It is especially suited for quantitative and graphical photo interpretation. Its modular expansion capability meets economic considerations. Integration in large photogrammetric systems is possible by computer linkage.

## Literature

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## Abstract

The G3 Stereocord is a simple analytical plotting system for numerical and graphical plotting work in photo interpretation and photogrammetry.

The equipment configuration consists of an opto-mechanical viewer for measuring 4 photo coordinates, an HP 85 or 86 desktop computer connected via a DIREC 2, and a software package with basic and optional software. Considerable enhancements are the capability to connect HP plotters (e.g. 9872 or the HP 7580 drum plotter) and the development of the powerful "GRAPHIC G3" software package for computer-controlled plotting.

Characteristics of the advanced G3 version are:

- Rigorous mathematical model, high precision
- Menu-driven interactive operation
- Data management with editing facilities
- Graphics software for the generation of any symbols, symbol lines, area filling with symbols, shading, map sheet preparation, profile measurement and profile plotting.
- Data transfer from the HP 85/86 to the HP 1000 for further processing with PAT-M and HIFI.

Typical applications are:

- Production of topographical and topical maps
- Quantitative photo interpretation in geology, forestry and planning
- Terrestrial plotting in architecture, archeology and engineering
- Point determination by aerotriangulation and measurement of digital elevation models
- Training of students in numerical and analytical photogrammetry and in computer-controlled plotting.

The versatility of the G3 system has thus been enhanced considerably.

## DAS ERWEITERTE LEISTUNGSSPEKTRUM DES ZEISS-STEREOCORD G3

### Zusammenfassung

Das Stereocord G3 als einfaches analytisches Gerätesystem dient der numerischen und graphischen Auswertung in Photointerpretation und Photogrammetrie.

Das Gerätesystem besteht aus einem optisch-mechanischen Grundgerät zur Messung von 4 Bildkoordinaten, einem über Direc 2 angeschlossenen Tischrechner HP 85 oder HP 86 und einem Softwarepaket mit Basissoftware und optionellen Programmen. Eine wesentliche Erweiterung stellt der Anschluß von HP-Plottern (z.B. HP 9872 oder Trommelplotter HP 7580) und die Entwicklung eines leistungsfähigen Programmpaketes "GRAPHIC G3" für rechnergesteuerte Kartierung dar.

Kennzeichen der weiterentwickelten G3-Version ist:

- Strenges mathematisches Modell, gute Genauigkeit
- Dialogorientierte Arbeitsweise mit Menüführung
- Datenverwaltung mit Editiermöglichkeiten
- Graphic-Software mit Erzeugung beliebiger Symbole, Symbollinien, Flächenführung mit Symbolen, Schraffur, Kartenblattvorbereitung und Profilmessung und Profilkartierung.
- Übertragung von Daten von HP 85/86 zu HP 1000 zur Weiterverarbeitung mit PAT-M und HIFI.

Beispiele für wichtige Anwendungen werden gegeben mit

- Herstellung topographischer und thematischer Karten
- Quantitative Photointerpretation in Geologie, Forstwesen und Planung
- Terrestrische Auswertung in Architektur, Archäologie und Ingenieurwesen.
- Punktbestimmung durch Aerotriangulation und Messung digitaler Höhenmodelle und
- Ausbildung von Studenten in numerischer und analytischer Photogrammetrie und in rechnergesteuerter Kartierung.

Die Vielseitigkeit des G 3 wurde somit erheblich erweitert.

## NIVEAU DE PERFORMANCE ACTUEL DU STEREORESTITUTEUR STEREOCORD G3

### Résumé

Le Stéréocord G3 est un stéréorestituteur analytique simple destiné aux travaux de restitution numérique et graphique pour la photointerprétation et la photogrammétrie.

Il se compose d'un appareil de base opto-mécanique pour la mesure des 4 coordonnées-cliché, d'un calculateur de table HP 85 ou HP 86 raccordé par l'intermédiaire de Direc 2 et d'une programmation comprenant le logiciel de base et des programmes optionnels. Les plus récentes innovations sont le raccordement de traceurs HP (par ex. HP 9872 ou le traceur à tambour HP 7580) et la mise au point d'un logiciel performant, le GRAPHIC G3, destiné à la cartographie commandée par ordinateur.

Caractéristiques du nouveau Stéréocord G3:

- Modèle mathématique rigoureux; excellente précision
- Mode de travail facilité par un dialogue et une liste d'options proposées à l'opérateur, dite "à la carte"
- Gestion des données avec possibilité de les manipuler (effacement, modification etc.)
- Programme de restitution graphique avec création de symboles, de lignes de symboles, remplissage de surfaces avec hachures ou signes conventionnels, avec préparation de la feuille de carte, mesure et tracé des profils
- Transfert des données du HP 85/86 vers un HP 1000 pour le traitement des informations avec des programmes PAT-M et HIFI.

Exemples d'applications typiques les plus importantes:

- Réalisation de cartes topographiques et thématiques
- Photointerprétation quantitative pour la géologie, la sylviculture et les plans d'aménagement du territoire
- Restitution de clichés terrestres pour l'architecture, l'archéologie et le génie civil
- Levé de points pour l'aérotriangulation et mesure de modèles altimétriques digitaux
- Formation des étudiants en photogrammétrie numérique et analytique et en cartographie commandée par ordinateur.

Ces nouveautés confirment le caractère polyvalent du Stéréocord G3.

## LA GAMA AMPLIADA DE POSIBILIDADES DEL STEREOCORD G3

### Resumen

El sistema instrumental analítico de tipo sencillo Stereocord G3 sirve para las restituciones numérica y gráfica en fotointerpretación y fotogrametría.

El sistema instrumental consta de un instrumento básico óptico-mecánico para medir cuatro coordenadas de imagen, una calculadora de sobremesa HP 85 o HP 86 conectada por intermedio de Direc 2 y un paquete de software básico y programas opcionales. Una ampliación esencial está representada por la conexión de trazadores HP (p. ej. HP 9872 o trazador de tambor HP 7580) y la elaboración del paquete de programas "GRAPHIC G3", de gran rendimiento y destinado al trazado de mapas, mandado por computadora.

La versión ampliada del Stereocord está caracterizada por las siguientes propiedades:

- Modelo matemático riguroso, excelente precisión
- Modo de trabajo por diálogo y facilitado por una lista de opciones propuesta al operador ("Menue")
- Gestión de datos con posibilidad de editado (borrado, modificación)
- Software gráfico para generar símbolos o signos discretos, líneas de símbolos, llenado de áreas con símbolos, rayados, preparación de hojas de mapas así como medición y trazado de perfiles.
- Transferencia de los datos desde las calculadoras HP 85/86 a HP 1000 para su procesamiento ulterior con PAT-M y HIFI

Citamos unos ejemplos importantes de aplicación:

- Confección de mapas topográficos y temáticos
- Fotointerpretación cuantitativa en geología, silvicultura y planificación
- Determinación de puntos para la aerotriangulación y medición de modelos altimétricos digitales
- Entrenamiento de estudiantes en fotogrametría tanto numérica como analítica así como en el trazado de mapas, mandado por computadora.

De esta manera, la versatilidad del Stereocord G3 ha sido ampliada considerablemente.

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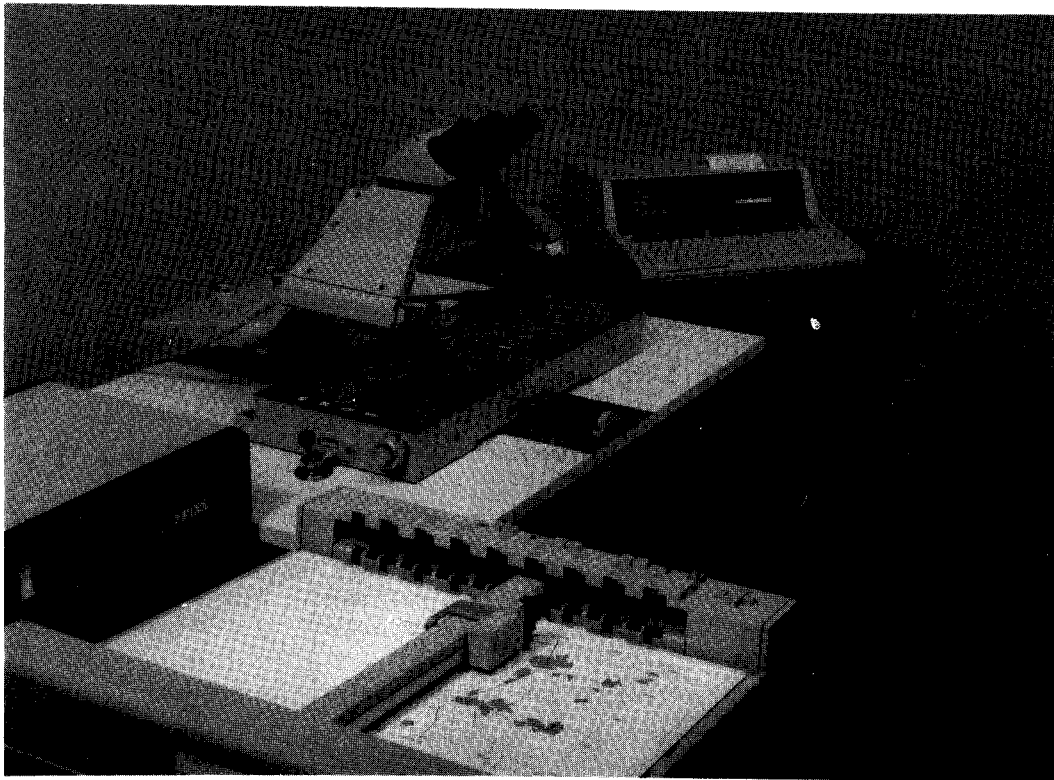


Fig. 1: G3 Stereocord Hardware

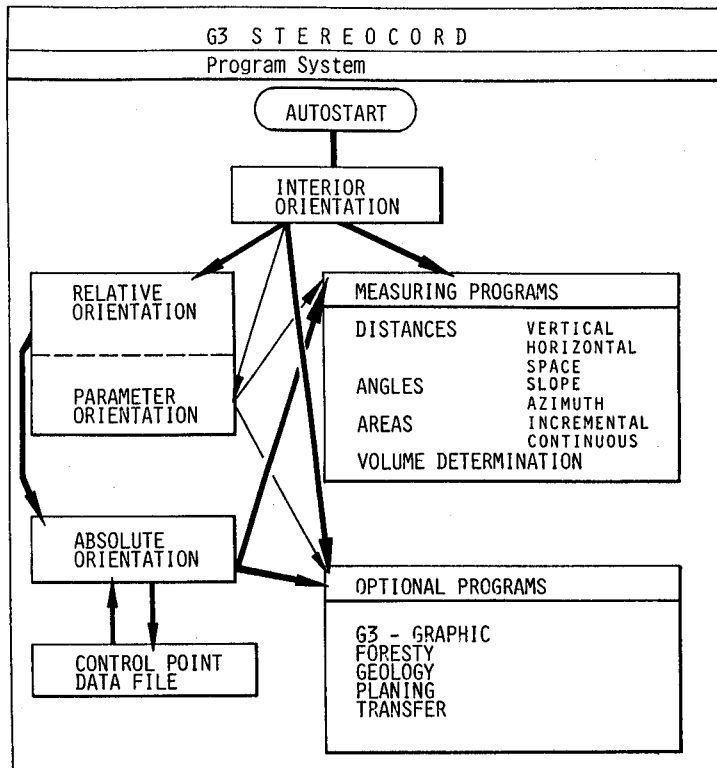


Fig. 2: G3 Stereocord Software Survey



```

    STEREOCORD HP 85
    MEASUREMENT PROGRAMS
    ? k1 REAL-TIME-DISPLAY
    ? k2 DISTANCES / ANGLES
    ? k3 AREAS
    ? k4 VOLUMES
    ? k5 AEROTRIANGULATION
    k6 CHOICE OF PROGRAMS (<>)
    k7 DIREC 2-REFERENCE-TEST
    k8 PARAMETER-LIST
    
```

```

    STEREOCORD HP 85
    VOLUMES
    ? k1 PROFILING STEPWISE
    ? k2 PROFILING CONTINUOUSLY
    k4 BACK TO OTHER PROGRAMS
    
```

```

    STEREOCORD HP 85
    VOLUME (PROFILING STEPWISE)
    * k1 PROFILE DIRECTION
    k2 FIRST PROFILE
    k3 NEXT PROFILE
    k4 R E S U L T
    ? k5 REFERENCE HEIGHT
    k6 REPEAT LAST PROFILE
    C k7 CHOICE OF RECORD MODE P
    k8 BACK TO OTHER PROGRAMS
    
```

Fig. 3: G3 Operator Guidance Menus (Example: Volume Determination)

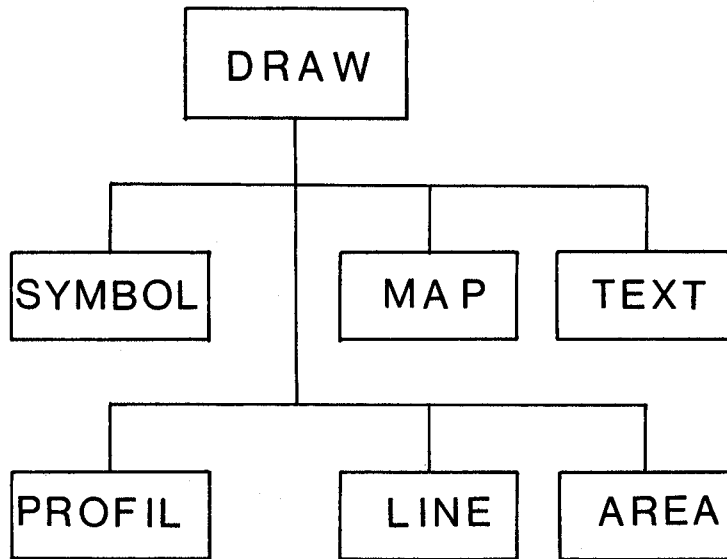


Fig. 4: G3-GRAPHIC Survey

SYMB. -NO.		
10		Cliff
11		Dam
12		Wall
13	< >	Fence
14	< >	High-voltage line
15	^	Conifers
16	o	Deciduous trees
17	~	Heath
18	~	Bog, swamp
19	~	Meadow

SYMB. -NO.		
0	△	Triangle
1	○	Circle
2	△	TP
3	⊕	Church
4	⊕	Chapel
5	⊕	Tower
6	⊕	Monument
7	→	Arrow
8	≡	Bridge
9	⌵	Mine

Fig. 5: Symbol Representation on the Graphics CRT

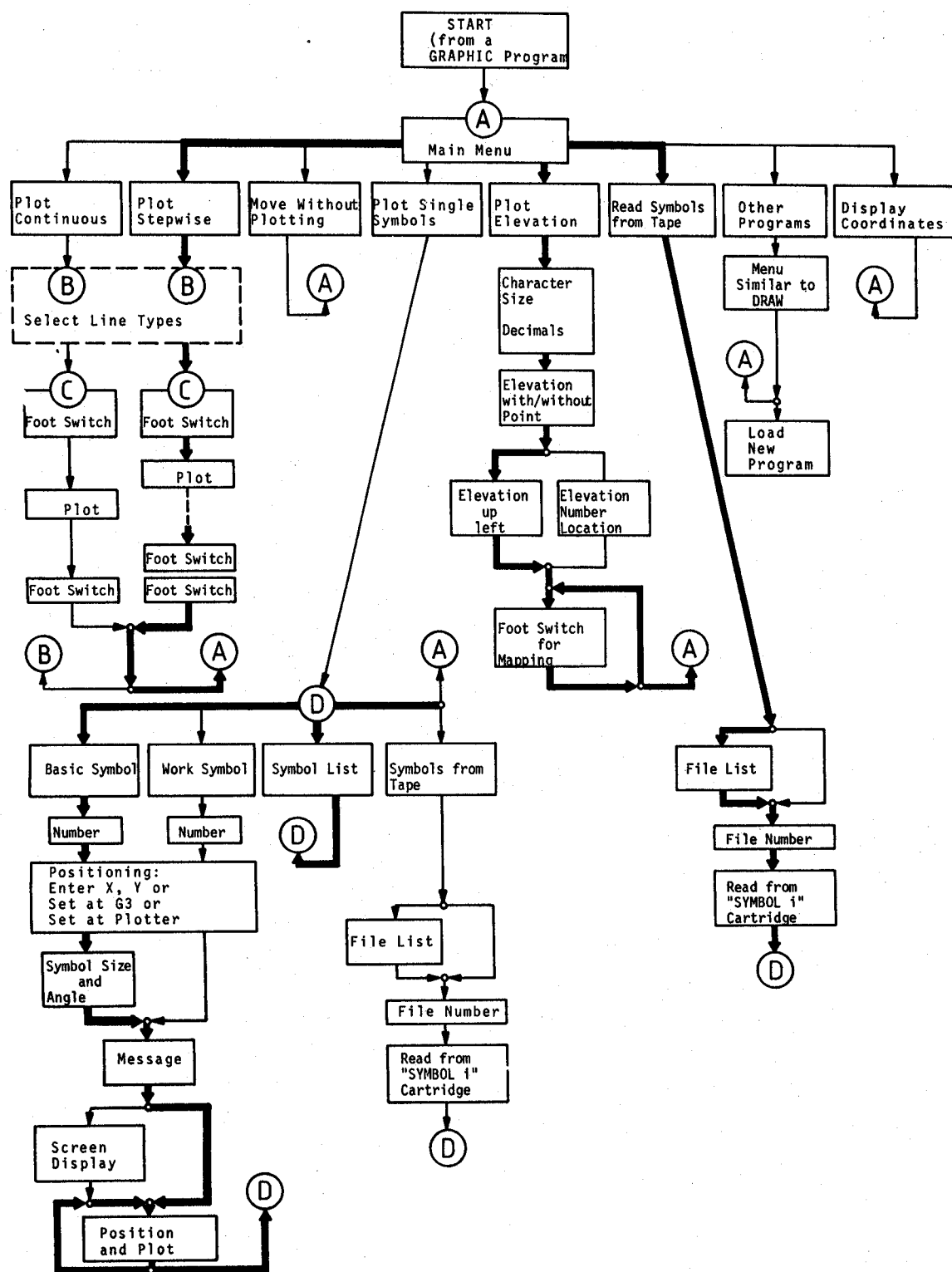


Fig. 6: G3-GRAPHIC LINE Program Flowchart

Geomorphologische Karte

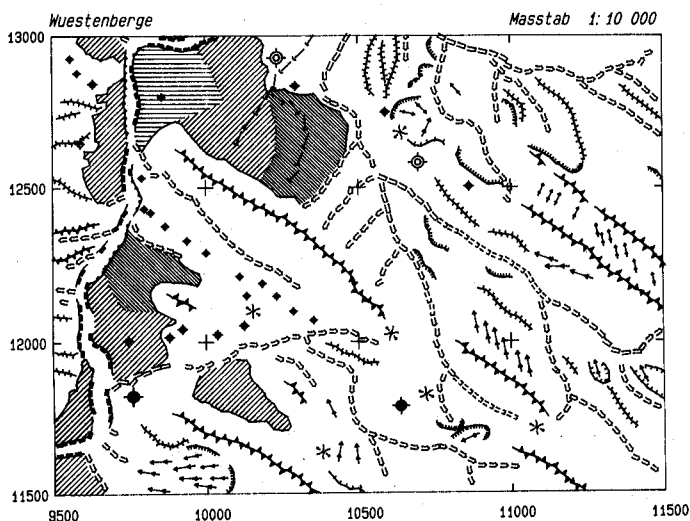
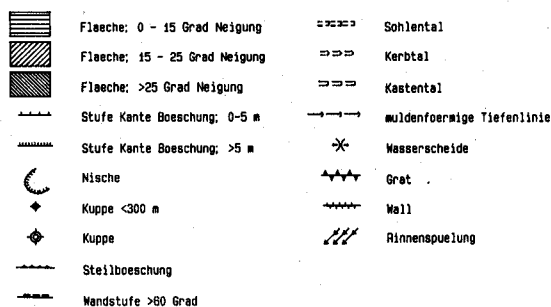


Fig. 7: Scale 1:10 000 Geomorphological Map

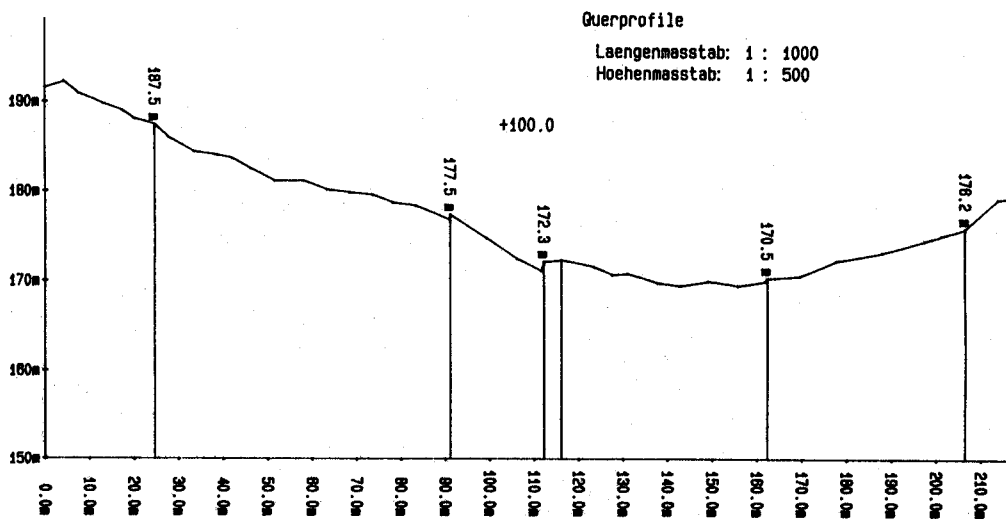
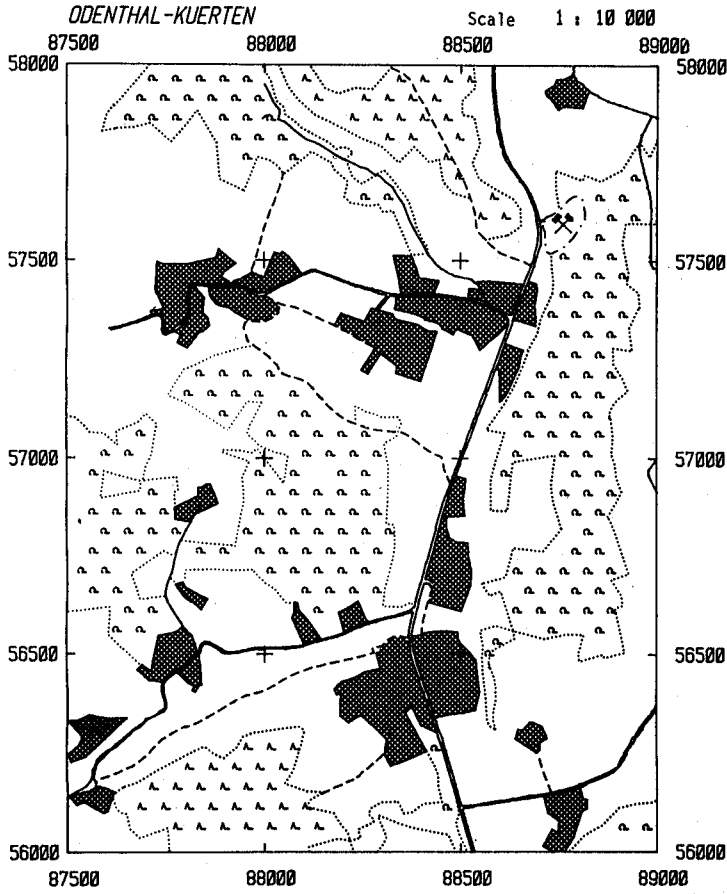
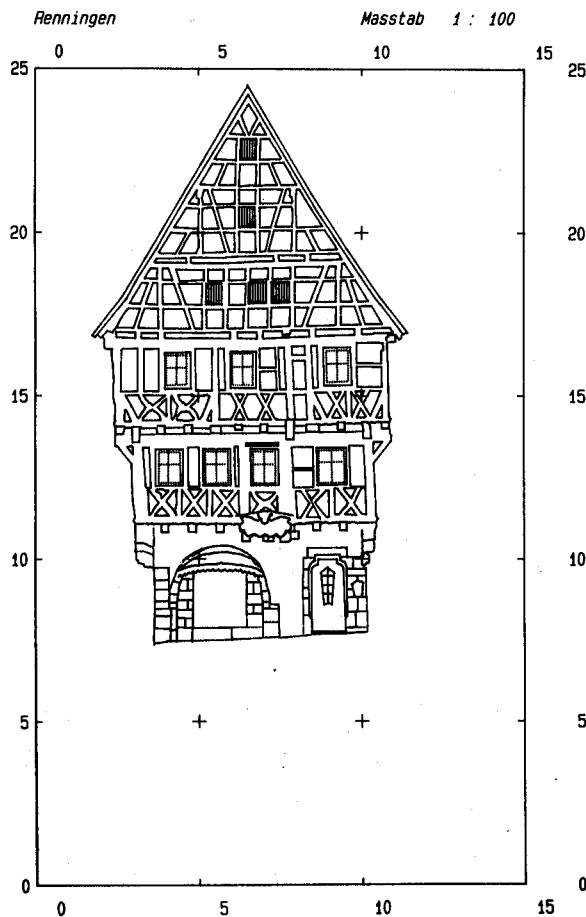


Fig. 8: Elevation Profile



**Fig. 9:** Scale 1:10000  
 Land Utiliza-  
 tion Plan



**Fig. 10:** Scale 1:100 Facade Plot