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BEDROCK DATABASES – A STEP TOWARD STANDARDIZED GEOLOGICAL INFORMATION

by
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For more than 100 years, geological surveys all over the world have been collecting their data sets as paper documents – notes, sketches, maps etc. For the last thirty years however, almost all the surveys have collected their mapping data sets into distinct and/or different databases. GTK also started to construct its first computerized bedrock databases at in the early 1980's, and all the bedrock processes, such as bedrock mapping, mineral exploration and urban mapping, have their own databases and standards for the storing of data.

The revolution in information technology (GIS and www services) led geological surveys to start developing methods in the mid-1990s for government geological mapping in accordance with the demands of the post-paper map era. In order to address these IT challenges, GTK also started its "Legacy data" and "Geokernel" projects at the beginning of 2000 for the purpose of recording new bedrock data (e.g. observations and map data) in databases constructed according to a consistent format, and it has now proceeded to adapt its early sets of survey material to the same database structures. Similarly, it has switched over to the use of rugged PCs for data acquisition purposes and adopted a uniform classification system for all its user interfaces.

GTK's bedrock mapping has moved over from its use of traditional map sheets to a single seamless bedrock map database (DigiKP), one essential part of which is a register of geological bedrock units (Finstrati) covering the entire country. A seamless bedrock map to a scale of 1:200 000 based on the DigiKP and Finstrati databases was released as an online product in March 2010. Both databases observe international stratigraphic standards and employ IUGS/GCI vocabularies.

Work on developing the bedrock databases will continue for a long time to come even after the old data, e.g. observation, commodity and map data, have been transferred to the new databases, because the increased dissemination of information at home and abroad is creating new demands (INSPIRE–GeoSciML–EarthResourceML).

Keywords (GeoRef Thesaurus, AGI): bedrock, mapping, data management, data bases, survey organisations, Finland

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INTRODUCTION

Where generations of earth scientists have summarised the results of their fieldwork and research in map form and field notebooks, geological survey agencies all over the world are now developing methods for government geological mapping in the post-paper map era. The Geological Survey of Finland (GTK), like most long-established surveys, is in the process of renewing its mapping strategies in the light of the revolution in information technology. Pressures for greater responsiveness to customer groups and the push for greater organizational efficiency are the main drivers behind this process. Web-based approaches are increasing in importance as they make it possible to query and exchange geoscientific information internationally.

GTK took its first steps towards the digital era in the mid-1980s, with the MS-DOS based PC-Kalpea and PC-Kaira user interfaces (Haavikko 1989, Kairakari 1989), which were the first observationdatabase software products adopted for bedrock and raw material mapping. Later, in the 1990s, some other processes, such as dimension stone, aggregate and urban mapping acquired user interfaces of their own. At the beginning of the 2000s, these PC interfaces were converted to the Windows environment and the database solution was RDB. More than 400 000 field observations have been stored in GTK's bedrock databases (Kalpea–Raki–Kiva–Taajama) over the last two decades.

GTK has a long history of constructing ore deposit databases. The first version was created in the mid-1970s (Saltikoff 1976), and many versions have been developed after that. Currently, GTK is using separate Access-based ore deposit databases for several metals and minerals (http://en.gtk.fi/ExplorationFinland/Commodities/).

All surveys have had different kinds of mapping programs in the course of their history, mainly ones based on map sheet partition. Systematic geological bedrock mapping has been going on at GTK for more than 100 years with different map scales and variable degrees of coverage:

- 1:400 000 – first map published in 1900 and the last in 1980 (100%)
- 1:100 000 – first map published in 1949 and the last in 2007 (57%)

Mapping at GTK was traditionally based on lithology, and it is only in the last 15 years that some map sheets have been based on geological units and lithology (e.g. Laajoki 2006). GTK has produced various 1:1 million scale geological maps during its 125-year history (Simonen 1980, Korsman et al. 1997) and GTK has published many digital map products during the last 15 years (e.g. Koistinen et al. 2001, Nironen et al. 2002, Räsänen et al. 2004).

Common to all GTK's historical geological data sets (digital or analogue) is that they have to a greater or lesser extent employed different data models and vocabularies (or have lacked any systematic vocabulary). The era of Information Technology (IT) that began in the last quarter of the 20th century changed the world of geosciences totally and irrevocably. As Loudon (2000) pointed out: "IT influences the way in which scientists investigate the real world, how they are organized, how they communicate, what they know and what they think. We are just at the dawn of that era."

Each geological organization has its own starting point, depending on its previous data management systems and mapping processes. Many surveys had plans to build seamless map databases for surficial and bedrock purposes. One significant planning project that started in the late 1990s at U.S. Geological Survey was for a seamless map of the USA. The key result of this planning process has undoubtedly been the North American Data Model – A Conceptual Model for Geologic Map Information (NADMSC 2004) – http://www.nadm-geo.org/). Several other surveys launched data model planning efforts and web-based data delivery services at much the same time, and finally, in 2005, many surveys came to recognize the importance of cooperation. This marked the starting point of the global activity coordinated by the IUGS (International Union of Geological Sciences)/CGI working group (Commission for the Management and Application of Geoscience Information), with the development of a conceptual geoscience data model mapped to a common interchange format, which was also demonstrated by the IUGS-CGI group (GeoSciML and OneGeology portal – see more info http://www.cgi-iugs.org/).

BEDROCK DATABASES

In order to address these IT challenges, GTK instigated the "Legacy data" and "Geokernel" projects at the beginning of the new century. The history of the "Geokernel" project is presented elsewhere in this special paper (Ahtonen et al. 2011). The idea of the project was that GTK should in the future have mapping capabilities that encompass the entire process from fieldwork and data capture to final map production and services. Another task was to evaluate the old "legacy data" and "unharmonised" databases and then migrate to new database structures. The largest issues to be tackled in the renewal process relate to data models and architecture, data capture and acquisition and the dissemination and delivery of information. The process has called for considerable resources and demands a wide variety of skills.

GTK's original plan, dating back a decade, featured centralized data storage based entirely on ESRI's Geodatabase data structure (Oracle/ArcSDE platform). Recently, the architecture has been divided into spatial (Oracle/ArcSDE) and non-spatial parts (Oracle, without SDE). The present bedrock database structure is illustrated in Figure 1.

This paper describes our achievements in the bedrock data management process during the first decade of 21st century. Examples of the significant changes that have occurred include filed data capture and interfaces with standardized domain lists, old data migration, a seamless bedrock map database with geological units and hierarchical vocabularies (according to IUGS/CGI GeoSciML lists – see http://www.geosciml.org/).

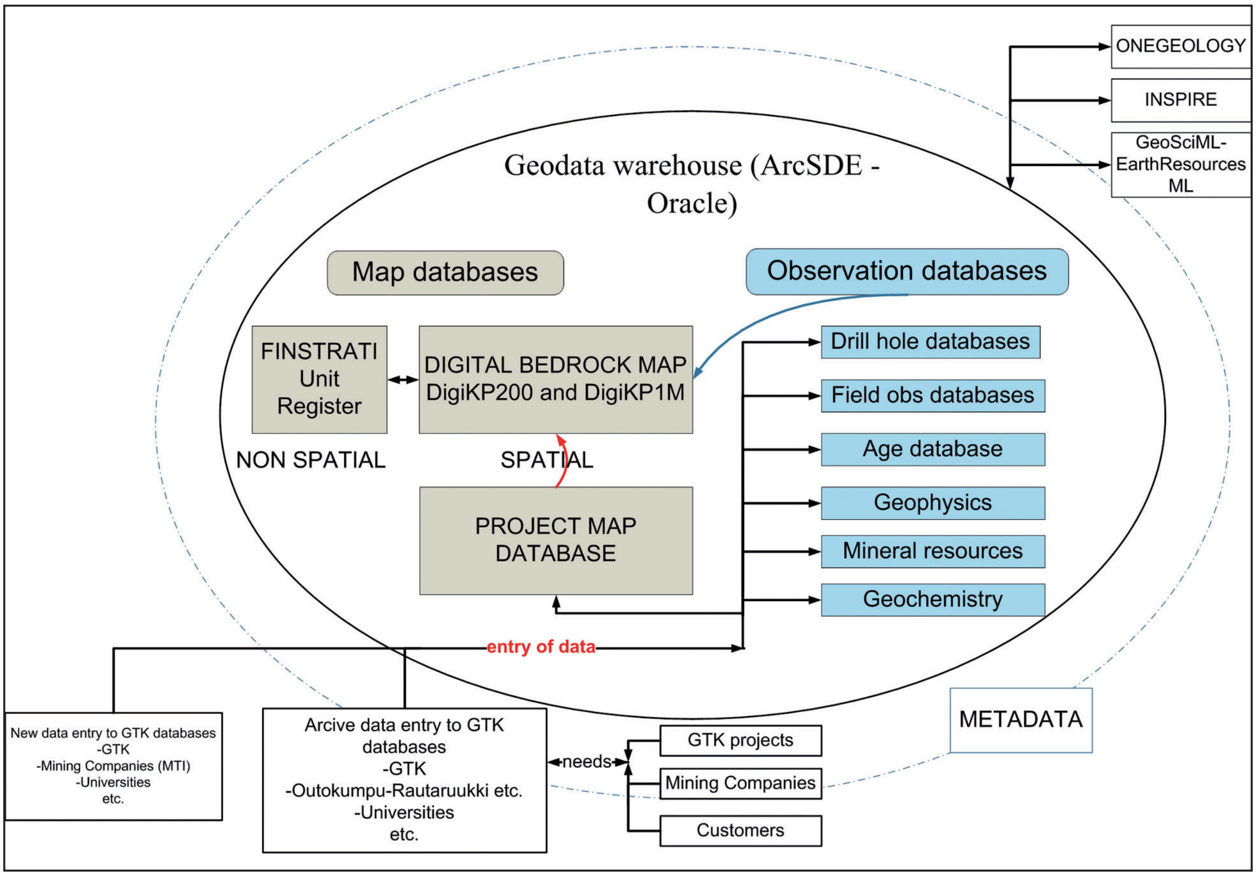

Figure 1. GTK's bedrock database structure. New data and maps – from archives and fieldwork – will be stored in observation and map databases. These can be used to update the harmonized seamless geology map database and map products to scales of 1:200,000 and 1:1 million that are linked to a non-spatial register of geological units.

The GTK field data capture solution – 2010

GTK has had many mapping processes during its history. All the previous data sets were collected in paper note books and on forms. Now we have created a new environment for the bedrock mapping process – to encompass the entire process from fieldwork and data capture to centralized database storage. In the future, GTK will implement a uniform, international standard data model updated to meet national demands with respect to field observations. One significant change compared with the past will be that all the processes have the same user interface, with uniform pick-up lists for bedrock outcrop and boulder data (Figure 2) and another for drill core logging data. The data model for bedrock observations covers such sub-processes as regional bedrock mapping, exploration, natural stone investigations and urban geology for construction purposes.

Field data capture will also be of importance for GTK in the future. As the data models used by GTK are complicated, we have focused especially on attribute editor development in software programming. Attribute editors are programmed on top of ArcGIS. Field data capture in the bedrock mapping process takes place by means of portable tablet PCs. Base maps, geophysical maps, previous observations, etc. are in digital format and can be used together in GIS software in the field. Bedrock observations are stored using standard ArcMap tools and customized editors.

GTK has digitalized (over 400 000) old field observations in various databases over the last twenty years, but these have mainly been saved in their native format, which means variable data structures and classifications. It has been a challenging process to convert all these old data sets to a new structure! The migration process will take up considerable resources and time, but it is these old data sets that will form the foundation of the new Finnish geological database which GTK and its customers will be using far into the future.

One good example of the challenges encountered during the conversion process concerns GTK's old outcrop observation database (KALPEA) and its quality problems. Almost all the data fields in the KALPEA database were saved as free text and only few data fields had specific domain lists. One key data field was of course rock name, and when migration started there were nearly 4000 such names to cope with (Figure 3a). In the course of the migration, all misspellings of the names were corrected and abbreviations were replaced with complete terms. Finally, all of these corrected rock names were transferred to the "Field Name" column, so that now there are only 2760 field rock names in the new database! Another example is rock colour – there were originally about 4600 colour names for rock types (Figure 3b), and now there are 179 left. The descriptions were first harmonized and then split during the migration process, after which the data were transferred and adapted to the new database structure and value lists (gcvd_Colour and gcvd_Colour attributes – Figure 3c).

GTK has transferred nearly all the field observation data sets to its new database structure during the last two years, marking the first step towards standardized geological data. This step will make our observation data much easier to use for various purposes in the future (e.g. www services).

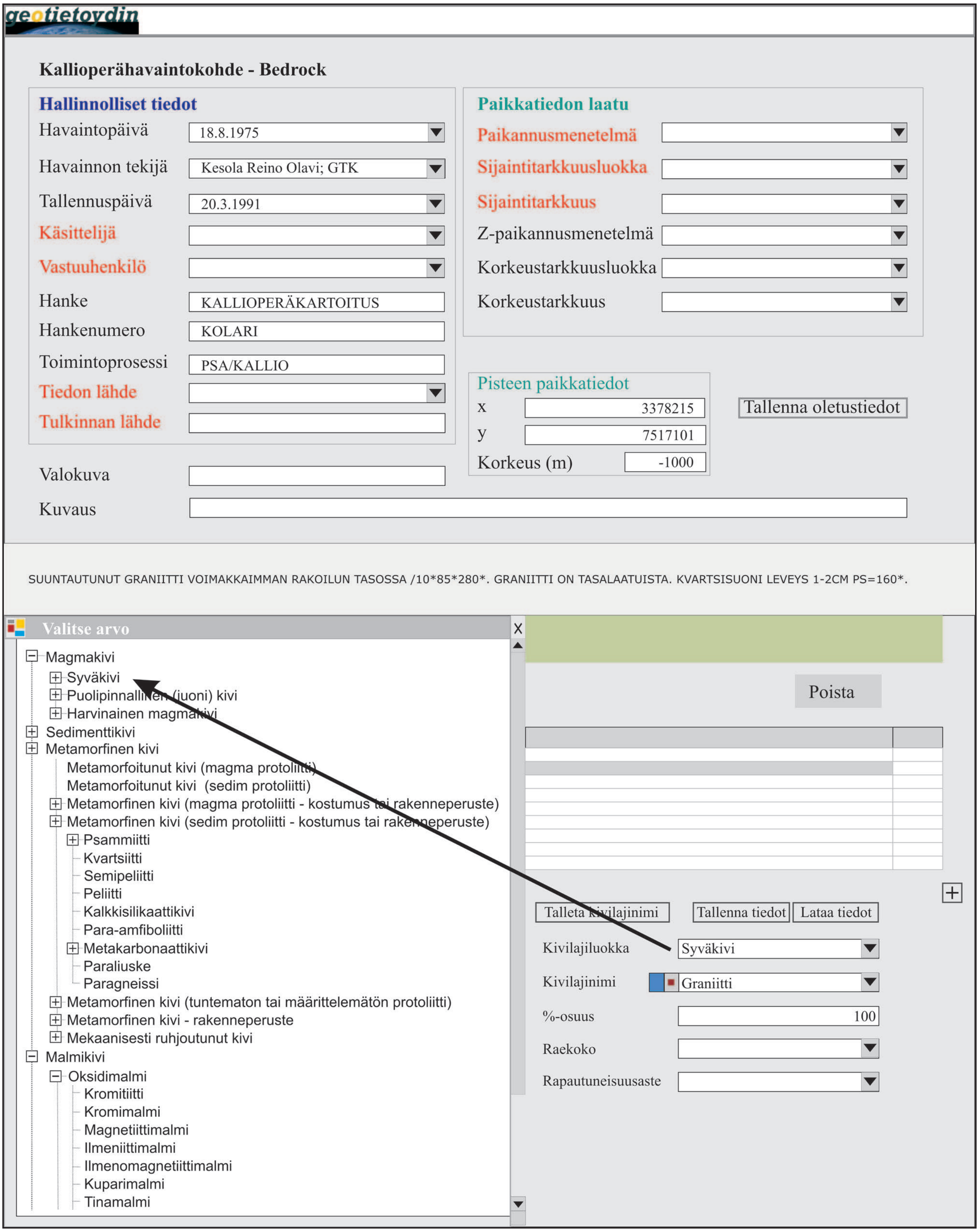

Figure 2. Part of the bedrock outcrop and boulder data capture interface “Kapalo” and the pick-up list of classified rock groups.

Kivilajit:Table

LKM	KIVILAJINIMI	KIVILAJINIMI_KORJATTU
1	AMFBOLIITTI	AMFIBOLIITTI
2	AMPHIBOLITE	AMFIBOLIITTI
1	AMFIBOLIITTI-KIVI	AMFIBOLIITTI
2	AMFIBOLIITTTI	AMFIBOLIITTI
1	AMFIBOLIITTIRAITA	AMFIBOLIITTI
3	PARA-AMFIBOLIITTI	AMFIBOLIITTI
1	SÄDEKIVI AMFIBOLIITTI	AMFIBOLIITTI
2	AMFFIBOLIITTI	AMFIBOLIITTI
1	AMFIBOLIITTI KERROS	AMFIBOLIITTI
21391	AMFIBOLIITTI	AMFIBOLIITTI
1	AMFIBOLIITI	AMFIBOLIITTI
1	AMFIBIOLIITTI	AMFIBOLIITTI
1	AMFIBOLIITTI.	AMFIBOLIITTI
2	AMFIBOLITTI	AMFIBOLIITTI
2	AMFIBOLIITTI(EMÄKSINEN VULKANIITTI)	AMFIBOLIITTI
84	AMFIBOLIT	AMFIBOLIITTI
1	AMFIBOLIIITTI	AMFIBOLIITTI
7	AMFIBOLIITTI/DIABAASI	AMFIBOLIITTI/DIABAASI
2	AMFIBOLIITTI/DIORIITTI	AMFIBOLIITTI/DIORIITTI
1	AMFIBOLIITTI/GABRO	AMFIBOLIITTI/GABRO
2	AMFIBOLIITTI/METADIABAASI	AMFIBOLIITTI/METADIABAASI
1	AMFIBOLIITTI/MEDIABAASI	AMFIBOLIITTI/METADIABAASI
2	AMFIBOLIITTI/ PERIDOTIITTI	AMFIBOLIITTI/PERIDOTIITTI
2	AMFIBOLIITTI/PERIDODIITTI	AMFIBOLIITTI/PERIDOTIITTI
3	AMFIBOLIITTI/SARVIVÄLKEGNEISSI	AMFIBOLIITTI/SARVIVÄLKEGNEISSI
1	AMFIBOLIITTI JA BIOTIITTIGNEISSI	AMFIBOLIITTI-BIOTIITTIGNEISSI
1	AMFIBOLIITTI-BIOTIITTILIUSKE	AMFIBOLIITTI-BIOTIITTILIUSKE
8	AMFIBOLIITTIBREKSIA	AMFIBOLIITTIBREKSIA
1	AMFIBOLIITTI-GABRO	AMFIBOLIITTI-GABRO
29	AMFIBOLIITTIGNEISSI	AMFIBOLIITTIGNEISSI

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A

Kivilajit väri:Table

LKM	VARI	VÄRI_KORJATTU
5	HAALEANPUNERTAVA	VAALEANPUNERTAVA
2	HAARMAA	HARMAA
1	HAARMAAN PUNAINEN	HARMAANPUNAINEN
2	HAMAA	HARMAA
1	HAMRAA	HARMAA
1	HAR	HARMAA
3	HAR.RUSKEA	HARMAANRUSKEA
3	HAR.RUSKEHTAVA	HARMAANRUSKEA
1	HARAMAA	HARMAA
1	HARAMAA-RUSKEA	HARMAANRUSKEA
1	HAREMAA	HARMAA
1	HARHAA	HARMAA
1	HARHAA, RUOSTEINEN	HARMAA
1	HARHAHTAVA	HARMAA
4	HARM.	HARMAA
4	HARM. PUNAINEN	HARMAANPUNAINEN
3	HARM. PUNERTAVA	HARMAANPUNERTAVA
1	HARM. PUNERTAVAA	HARMAANPUNERTAVA
1	HARM. RUSKEHTAVA	HARMAANRUSKEA
1	HARM. SININEN.	HARMAANSININEN
1	HARM. VIHERTÄVÄ	HARMAANVIHREÄ
1	HARM. VIHREÄ	HARMAANVIHREÄ
1	HARM./PUNAINEN	HARMAANPUNAINEN
1	HARM./VIHERT. ?	HARMAANVIHREÄ
1	HARM.+PUN.	HARMAANPUNAINEN
5	HARM.KIRJAVA	HARMAANKIRJAVA

Record: 1 of 4559

B

A	B	C	D
Koodi	**Arvo**	**Domainin nimi**	**Tietotyyppi**
-1	Ei arvoa	gcvd_Colour	int
1	Vihreä	gcvd_Colour	int
2	Harmaa	gcvd_Colour	int
3	Keltainen	gcvd_Colour	int
4	Violetti	gcvd_Colour	int
5	Musta	gcvd_Colour	int
6	Oranssi	gcvd_Colour	int
7	Punainen	gcvd_Colour	int
8	Ruskea	gcvd_Colour	int
9	Sininen	gcvd_Colour	int
10	Tumma	gcvd_Colour	int
11	Vaalea	gcvd_Colour	int
12	Valkoinen	gcvd_Colour	int
13	Kirjava	gcvd_Colour	int
93	Vaaleahko	gcvd_Colour	int
94	Tummahko	gcvd_Colour	int
95	Ruskehtava	gcvd_Colour	int
96	Harmahtava	gcvd_Colour	int
97	Lila	gcvd_Colour	int
98	Punertava	gcvd_Colour	int
99	Vihertävä	gcvd_Colour	int

E	F	G	H
Koodi	**Arvo**	**Domainin nimi**	**Tietotyyppi**
-1	Ei arvoa	gcvd_Colour_attributes	int
6	Punaisen	gcvd_Colour_attributes	int
7	Sinisen	gcvd_Colour_attributes	int
95	Valkoisen	gcvd_Colour_attributes	int
96	Punertavan	gcvd_Colour_attributes	int
97	Mustan	gcvd_Colour_attributes	int
98	Keltaisen	gcvd_Colour_attributes	int
99	Vihertävän	gcvd_Colour_attributes	int
22730001	Vaalean	gcvd_Colour_attributes	int
22730002	Tumman	gcvd_Colour_attributes	int
22730003	Harmaan	gcvd_Colour_attributes	int
22730004	Puna-	gcvd_Colour_attributes	int
22730005	Kelta-	gcvd_Colour_attributes	int
22730006	Sini-	gcvd_Colour_attributes	int
22730007	Vihreän	gcvd_Colour_attributes	int
22730008	Ruskean	gcvd_Colour_attributes	int
22730009	Lilan	gcvd_Colour_attributes	int
22730010	Oranssin	gcvd_Colour_attributes	int
22370098	Musta-	gcvd_Colour_attributes	int
22730099	Valko-	gcvd_Colour_attributes	int

C

Figure 3a. The Kalpea database – primary field name (*kivilajinimi*) and corrected field name.
Figure 3b. The Kalpea database – primary colour (*väri*) and corrected colour (*värikorjattu*).
Figure 3c. Domain lists (gcvd_Colour/ and gcvd_Colour_attributes) in the new database.

THE GTK SEAMLESS BEDROCK MAP DATABASE – 2010

Another important component of the bedrock database design has been a seamless bedrock map database for Finland. The idea of GTK's seamless map database goes back to the beginning of the 2000s, but the actual work on building the database started in 2005. The decision to put an end to GTK's 1:100 000 bedrock mapping programme and the need to achieve a uniform presentation of the bedrock of Finland led to the implementation of a digital bedrock map database project called *DigiKP*, the aim of which was to produce a uniform seamless vector bedrock map to a scale of 1:200 000. The project was active in 2006–2009 and practically all the bedrock geologists in the GTK were involved in it.

The first plans for the database structure were based on traditional lithological mapping. However, even with careful planning, the process has not been straightforward. The first plan was replaced with a new approach at 2007. A new data model based on the NADM-C1 (NADMSC 2004) definition and supplemented according to national needs. The original plan for centralized storage based on an ESRI Geodatabase data structure (Oracle/ArcSDE platform) has also been revised and the databases are now divided into spatial (Oracle/ArcSDE) and non-spatial parts (Finstrati, the geological unit register with attribute data in relational databases). The idea of a divided architecture came from the plan of Geoscience Victoria of Australia (GSA) for a map database solution. Their primary plan was to store everything in an ESRI Geodatabase, but after an evaluation process a combination of RDBMS and GIS technology was selected (Simons et al. 2005).

The 1:100 000 bedrock map sheets of Finland were the most important source of data for the new map, especially where Southern and Central Finland were concerned. The areas without such maps were covered by 1:200 000 and 1:400 000-scale maps, and more detailed data (scale 1:4000–1:10 000) were available for some areas. A large number of maps (scale 1:10 000–1:20 000) produced by the Outokumpu company were also used as source data. For some areas in northern Finland, the relevant maps were lacking and were interpreted and digitized on the basis of outcrops and low-altitude airborne geophysical data.

Because of the great variety in the scale of the source data, the original idea of a map database to a scale of 1:200 000 was exchanged for a seamless map database without any specific scale. The product, termed DigiKP, is intended to be GTK's primary bedrock map database and will be updated regularly in the future. The products based on this primary map database will be maps to scales of 1:200 000 and 1:1 000 000. The former is a product that will be available for customers in the form of specified map sheets and data and also as an Internet map service (Figure 4a – http://www.geo.fi/en/bedrock.html), while the latter will be a simplified bedrock map database covering the entire area of Finland.

A database of stratigraphic geological units (Finstrati) was also developed during the DigiKP project by extending the division of the bedrock into stratigraphic units that had formerly been in use only in Northern Finland to cover the whole country. Almost 2000 lithostratigraphic or lithodemic units were generated and described. The units were first stored with an MS Access-based system and will subsequently be incorporated into the GTK geodatabase. The nomenclature was generated according to international rules (North American Commission on Stratigraphic Nomenclature 2005) and in co-operation with the Stratigraphic Commission of Finland. Most of the database value lists (e.g. unit, contact_type, process, environment and event – Figure 4b) are based on hierarchical classifications vocabularies and have been adopted from IUGS–CGI work. These classifications will facilitate our plans to use the database for interoperability purposes in the future (e.g. INSPIRE–OneGeology–GeoSciML–EarthResourceML)

Stratigraphic codes are included in the map database as attribute data. This is a huge improvement on earlier bedrock maps, which had only lithology coding. In the first stage (version 1.0), the bedrock map database in the Geokernel system (Finn. *Geotietoydin*) is composed of polygonal geological units, source data and quality layers together with a line-based structure layer, but there are plans to add dyke, metamorphic, structural analysis and ore potential maps, among others, to the database in the future. Both the map database and the stratigraphic unit database will be updated regularly.

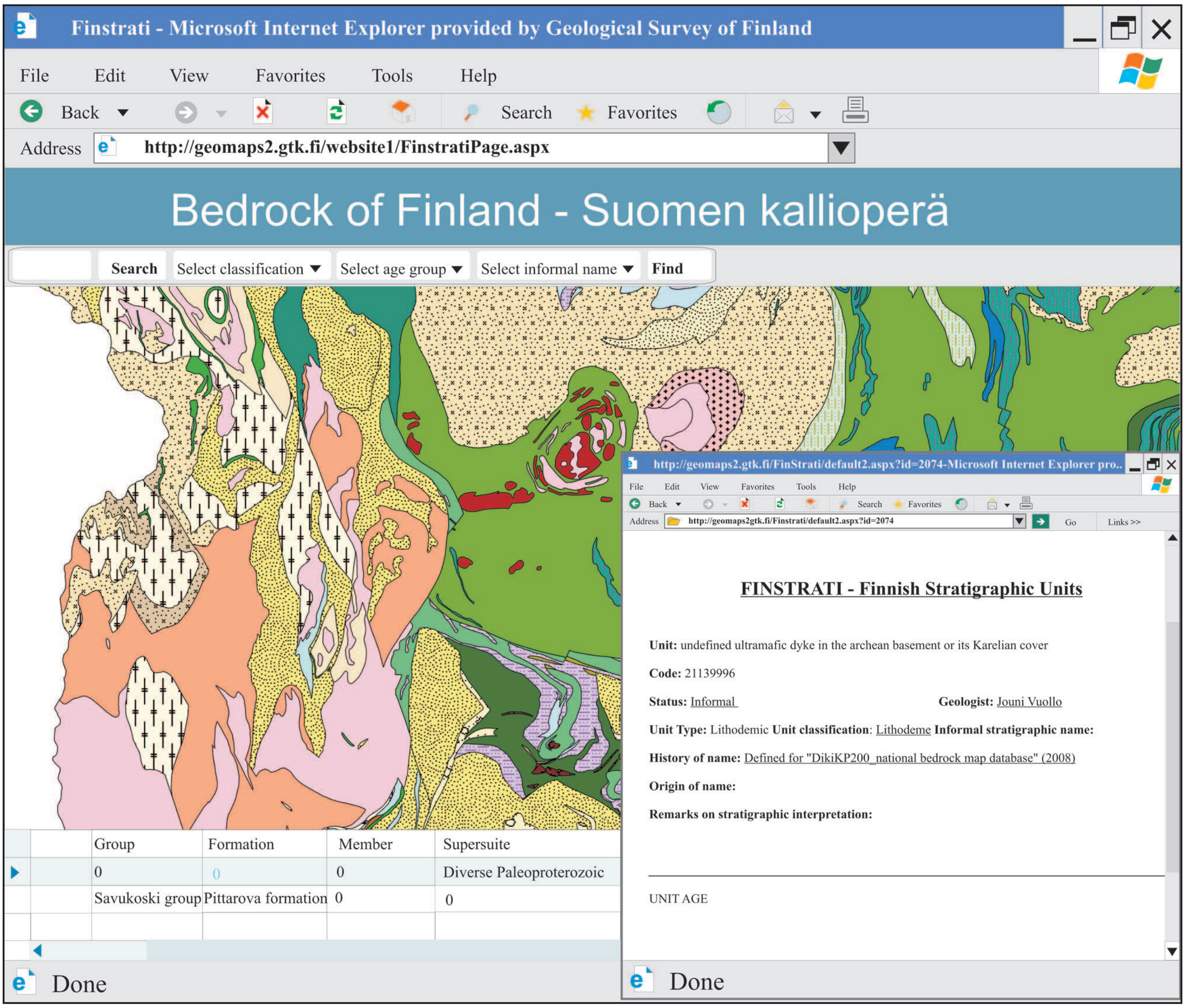

Figure 4a. Snapshot from “Bedrock of Finland” – the service opened on 5.3.2010.

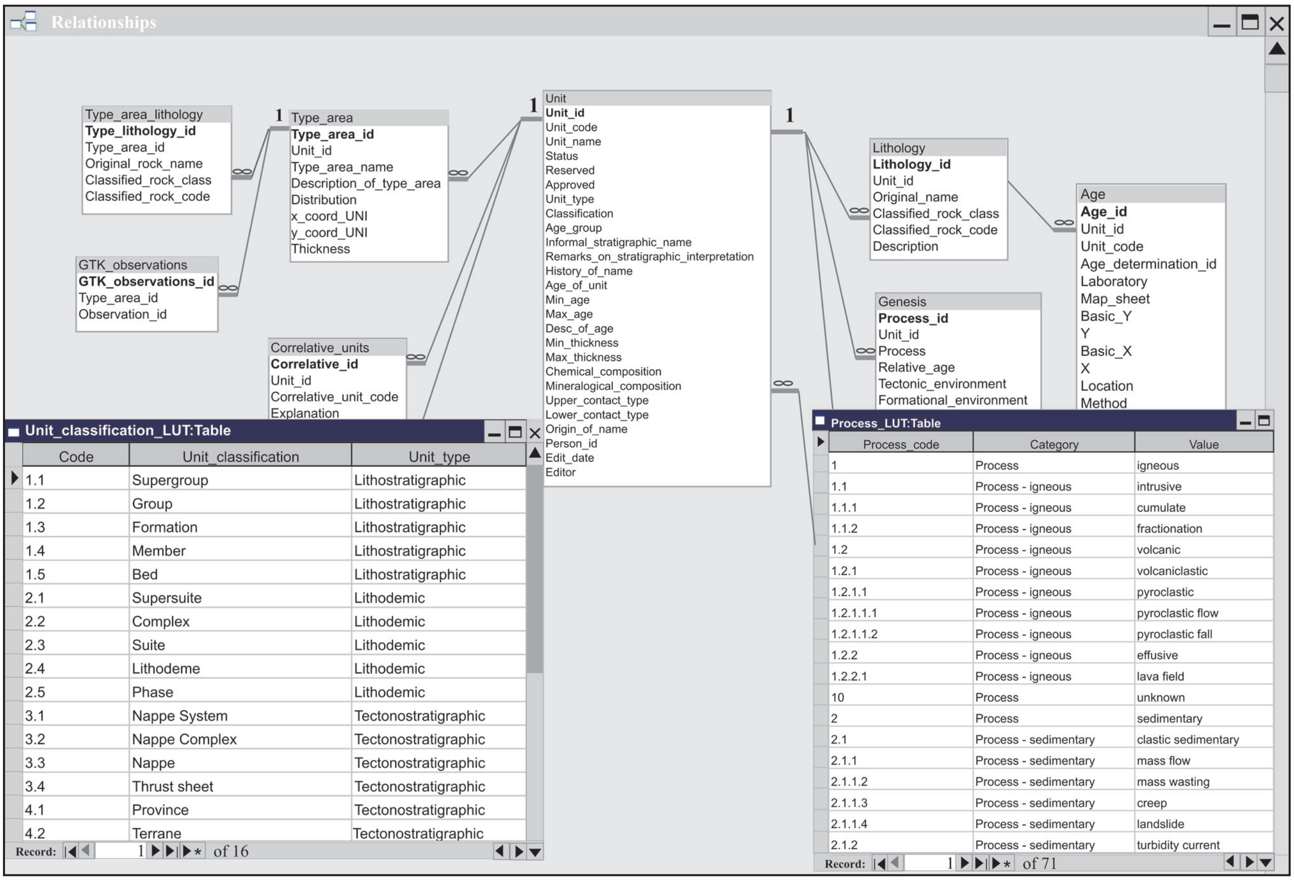

Figure 4b. The data model and code lists for Finstrati.

FUTURE PLANS

Many factors that constrained our predecessors no longer exist. Modern computing systems (GTK's new databases, GIS and Internet tools) allow us to store, retrieve and present far more information and knowledge than we could ever show on two-dimensional paper maps. The whole data capture process has changed in the last few years with the introduction of rugged PCs and GPS receivers, and all data sets can also be made available in the field. At the same time, web services and the needs for interoperability impose new challenges. These changes have created a totally new range of possibilities and challenges for our geological databases – in terms of structure, standardization and above all data quality. Examples of the challenges include the questions of how to manage the workflow from project maps and other data sets in GTK's seamless bedrock map database (DigiKP) and how to create a workable updating process for this database and its products.

GTK´s vision is of being a national geoinformation centre finding ways to make numerical datasets accessible, relevant, and easy to use. Interoperability in Europe due to the EU's INSPIRE directive (http://www.inspire-geoportal.eu/) and global collaboration (OneGeology; http://onegeology.org/) requires normative conceptual data models, classification systems, and common geological terminology. For this purpose, GTK is moving towards harmonized databases, governed largely by the recommendations of the INSPIRE directive and the technical specifications contained in the emerging data transfer standard e.g. GeoSciML (http://www.geosciml.org/)–EarthResourceML (http://www.earthresourceml.org/). International networking, for instance with the IUGS–CGI [http://www.cgi-iugs.org/], NADM [http://nadm-geo.org/] and GeoSciM–EarthResourceML teams, plays a significant role in this harmonization process.

Supplementary information on the web:

http://en.gtk.fi/ExplorationFinland/Commodities/
http://www.cgi-iugs.org/
http://www.geosciml.org/
http://www.earthresourceml.org/
http://www.geo.fi/en/bedrock.html
http://www.inspire-geoportal.eu/
http://onegeology.org/

REFERENCES

Ahtonen, N., Lalli, K., Kauniskangas, E. & Vuollo, J. 2011. The implementation of GTK's management and distribution system for geoscience data. In: Nenonen, K. & Nurmi, P. A. (eds.) Geoscience for Society. 125th Anniversary Volume. Geological Survey of Finland, Special Paper 49.

Haavikko, J. 1989. Program manual for drill hole logging – PC-micro (Syväkairausreikien raportointiohjelman käyttöohje PC-mikroille – unpublised manual. (in Finnish)

Kairakari, H. & Kähkölä, H. 1989. Program manual for bedrock observations. (Kallioperäkartoitustietojen ylläpito-ohjelma (Kalpea) – unpublised manual. (in Finnish)

Koistinen, T., Stephens, M. B., Bogatchev, V., Nordgulen, Ø., Wennerström, M. & Korhonen, J. 2001. Geological map of the Fennoscandian Shield, scale 1:2 000 000. Geological Survey of Finland, Special maps 48.

Korsman, K., Koistinen, T., Kohonen, J., Wennerström, M., Ekdahl, E., Honkamo, M., Idman, H. & Pekkala, Y. (eds.) 1997. Bedrock map of Finland 1:1 000 000. Geological Survey of Finland, Special maps 37.

Laajoki, K. 2006. Puokiovaara. Geological Map of Finland 1:100 000, Pre-Quaternary Rocks, Sheet 3441. Geological Survey of Finland. (Electronic publication)

Loudon, T. V. 2000. Geoscience after IT: a view of the present and future impact of IT on geoscience. Oxford: Elsevier. 142 p.

NADMSC (North American Data Model Steering Committee) 2004. NADM conceptual model 1.0. A conceptual model for geologic map information: U.S. Geological Survey Open-File Report 2004-1334. 60 p.

Nironen, M., Kuosmanen, E. & Wasenius, P. 2002. Keski-Suomen granitoidikompleksi – Central Finland Granitoid Complex. Kallioperäkartta – Bedrock map 1:400 000. Geological Survey of Finland, Special maps 55.

North American Commission on Stratigraphic Nomenclature 2005. North American Stratigraphic Code: AAPG Bulletin, v. 89, No.11, 1547–1591. Available at: http://ngmdb.usgs.gov/Info/NACSN/Code2/code2.html.

Räsänen, J., Iljina, M., Karinen, T., Lauri, L., Salmirinne, H. & Vuollo, J. 2004. Geological map of the Koillismaa area, Northeastern Finland 1:200 000. Geological Survey of Finland, Special maps 59.

Saltikoff, B. 1976. Malmikarttatiedoston käsittelyohjelmisto. Geeological Survey of Finland, unpublished report M16/76/1. 3 p. + 16 appendices.

Simonen, A. 1980. Suomen kallioperä 1:1 000 000. Pre-Quaternary rocks of Finland. Finlands berggrund. Reprint 1990. Geological Survey of Finland, Special maps 12.

Simons, B., Ritchie, A., Bibby, L., Callaway, G., Welch, S. & Miller, B. 2005. Designing and building an object-relational geoscientific database using the North American Conceptual Geology Map Data Model (NADM-C1) from an Australian perspective: Proceedings of IAMG'05: GIS and Spatial Analysis, v. 2, 929–934.