Radon risk mapping of the Czech Republic on a scale 1 : 50 000

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Abstract

A new type of radon risk maps on a scale 1 : 50 000 was published in the Czech Republic. Maps are based on the vectorized countours of geological units and rock types and field soil gas radon measurements from the radon database. Radon risk is expressed in four categories . More detailed topography enables to predict the radon risk from bedrock in the intravilans of villages and towns.

Introduction and overview of research and mapping programme

The radon risk mapping programme started in the Czech Republic ten years ago. The programme is based on the close cooperation with the State Bureau of Nuclear Safety and the National Radiation Protection Institute. Both institutions deal with the distribution and evaluating of track-etch detectors in particular dwellings. As radon is generated in the bedrock, the Czech Geological Survey offered its experience in geological knowledge of the state territory to help to find out the areas where indoor radon levels could exceed the action level (200 $Bq.m^{-3}$ equivalent equilibrium concentration - EEC).

The most important research and mapping activities performed by the Czech Geological Survey as well as the legislative acts concerning the radon programme during ten years are shortly summarized in the following overview. Most of these topics are extended in books of abstracts Radon investigations in Czechoslovakia I-IV and workshop abstracts Geological Aspects of Radon Risk Mapping V-VII . The latest legislative support to the Czech radon programme was given in 1999 by the Government Decision No.538 on the „Radon Programme of the Czech Republic", expressing the interest of government to protect the population against the enhanced level of natural radiation.

1990 – Radon risk classification for building site assessment published
Interministerial Radon Commission established
Radon risk maps 1 : 200 000 published for the whole state area

1991 – Decree of Ministry of Health No. 76 „ On the lowering of radiation from radon and other natural radionuclides " issued

1992 – study of tectonic influence on radon concentration
study of climatic variation of radon in soils

permeability influence on radon concentration
soil gas radon database established

1993 – Association Radon Risk, joining private radon companies established
seasonal radon variations
depth relationship of radon concentration
reference test sites established
study of radon in the black shales
Decree of Government No. 709 on the „ Protection of Public from the Radiation Caused by Radon and other Natural Radionuclides" issued

1996 – comparison of regional and local geology to indoor radon
study of influence of depth of sampling on the building site assessment
choice of new reference test sites in Central Bohemia
factors influencing the radon entry into houses
radon variations and Earth tidal deformations

1997 – Decree of the State Bureau of Nuclear Safety No. 184 on the „ Demands on the radiation protection" published

1998 – vectorization of geological and radiometric map 1 : 500 000
study of inconsistence between geological prediction and indoor radon results
influence of tectonics on radon concentration

1999 – radon risk map 1 : 500 000 published on the CD
16 detailed radon risk maps 1 : 50 000 published
nouvellization of building site assessment published
Government Decision No.538 on the „Radon Programme of the Czech Republic"

The background for radon risk maps 1 : 50 000

GeoČR50 – GIS of digital geological maps 1: 50 000

The process of creation of geodatabase GeoČR50 was divided into four main steps:
1. Vectorization
2. Implementation of digital maps into GIS
3. Creation of database of unified geological legend
4. United national geodatabase GeoČR50

1) The vectorization of geological maps has been started in 1995 within the framework of the fundamental project of CGS called "Geological mapping and the creation of special purpose environmental maps at the scale 1 : 50000". This project that covered 13 different thematic maps was started in 1985 and finished by the end of 1998. During that time more than 2000 maps (author's manuscripts) were completed and over 1500 were published. By the end of 1997 the vectorization of all 214 geological maps that cover the whole area of the Czech Republic was finished including those maps, where the technical standards were not met. This usually happened with the first vectorized maps. Technical solution for vectorization (software platform) comprises Microstation95 (Bentley Systems), I/RasB, I/RasC and I/Geovec (Intergraph).

2) The implementation of digital maps into GIS. This process is very specific in case of geological maps because of the presence of graphical elements (for example - faults) that partly do and partly do not create boundaries of polygons of lithological formations, the presence of large complex elements (polygons with more than 10 000 vertexes) or existence of special regions (holes) inside other regions etc.

The structure of recent data model has been created in the software environment MGE v. 7.1 in connection with RDBMS Oracle 8 on the Windows NT v.4.0 platform. The data model consists of 259 features divided into four categories. The whole geodatabase consists of over 260 000 records.

3) The creation of database of unified geological index started in 1997 and was finished in 1999. This database was an essential step for the creation of a unified (without geological boundaries on the edges of map sheets) national geological database – GeoČR50. The database of geological legend consists at present of 2126 different geological units and covered four major types of information:

Chronostratigraphical units
Lithological description of rocks
Lithostratigraphical units
Regional units

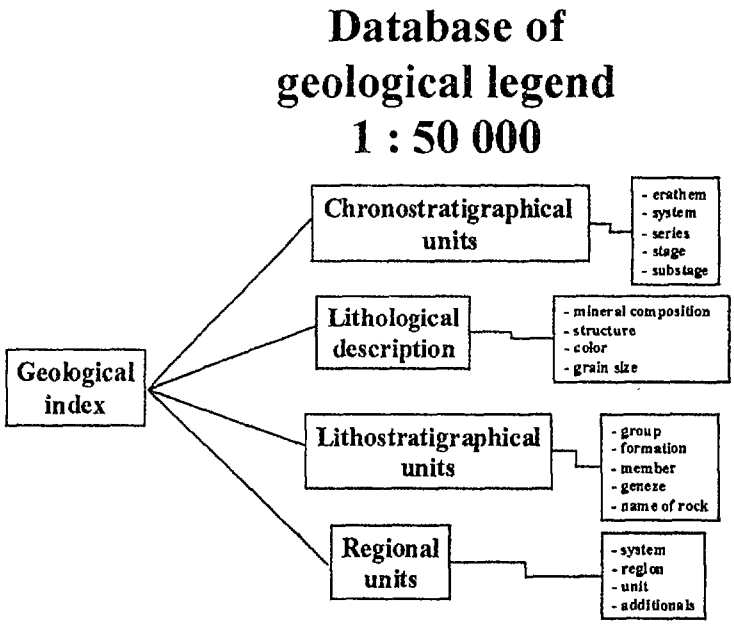


Fig. 1 – Database of geological legend 1 : 50 000

4) In 1999 the final completion of united geodatabase GeoČR50 was started within the internal CGS project and is estimated to be finished in 2 years. Even though the national geological database is not completely finished (connecting geological bodies among map sheets) the use of

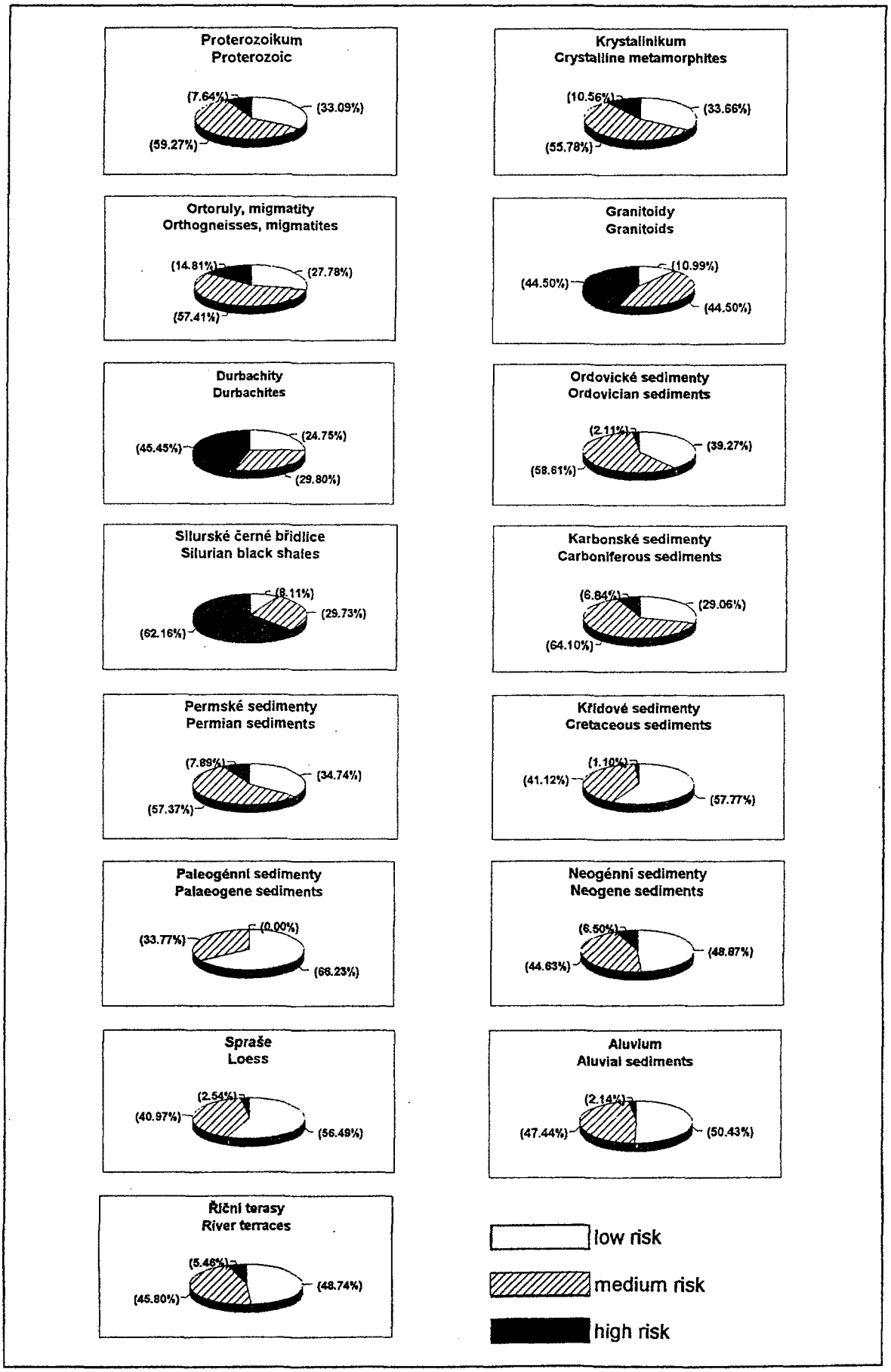


Fig. 2 - The distribution of radon risk in major rock types of the Czech Republic

such a system for environmental studies is tremendous. There are several fields where GIS of geological maps can be successfully used as for example in radon risk mapping.

Soil gas radon database

Since 1992 the Czech Geological Survey has been collecting the data coming from soil gas radon measurements for building site assessment. In details, the database contents was described in the previous book of abstracts Geological Aspects of Radon Risk Mapping VII (1998). The data coming from our measurements and private companies' measurements are obtained by uniform method based on the calibration of instruments in radon chamber and field comparison at the reference test sites. Up to now, the database contains the results from 8000 test sites (15 measurements each).

Radon risk mapping

The first radon risk maps were made in 1990, on a scale scale 1 : 200 000, covering the whole state area. Increasing number of data in the radon database enabled to publish the radon risk map on a scale 1 : 500 000 on the CD. More information on the mapping programe is available at www.cgu.cz (info, primary projects, radon risk).

Since 1999, the Czech Geological Survey has been using the vectorized geological maps on a scale 1 : 50 000, enabling to produce more detailed radon risk maps. The principle is partly similar to generalized radon risk map on a scale 1 : 500 000, but the raster topography for the whole state territory (214 map sheets 1 : 50 000) is much more detailed. Therefore the more precise determination of radon risk from bedrock in particular villages and towns is possible. These maps (programme started in June 1999) will be used by the State Bureau of Nuclear Safety and municipal authorities for distribution of the track-etch detectors within villages and cities.

Usually at each geological map 40-90 rock types are specified. The rock types differ mostly by mineralogical composition or by stratigraphic position, the difference in primary uranium concentrations and subsequently in radon activity is not so expressive. In combination with results from the radon database the particular rock types can be grouped into prevailing categories of radon risk (see fig. 2) . The rock units are divided into four categories of radon risk – low (mostly for younger sedimentary formations from Cretaceous to Neogene), interstage (inhomogeneous Quaternary sediments), medium (Palaeozoic sediments and crystalline gneisses) and high (mostly granitoids).

The coordinates of sampling sites are digitized in Didger programme and loaded into the radon database. Grouping of vectorized geological units is performed in MGE programme and transformed into Microstation programme (Bentley), where the grouped contours of rock units are filled according to the prevailing category of radon risk. The whole software procedure is illustrated in fig. 3 . The test sites' positions are loaded over the vectorized radon layer and topographic raster files (intravilan plans, road network and watersheds) are attached. However these maps do not substitute the building site assessment on the building lots.

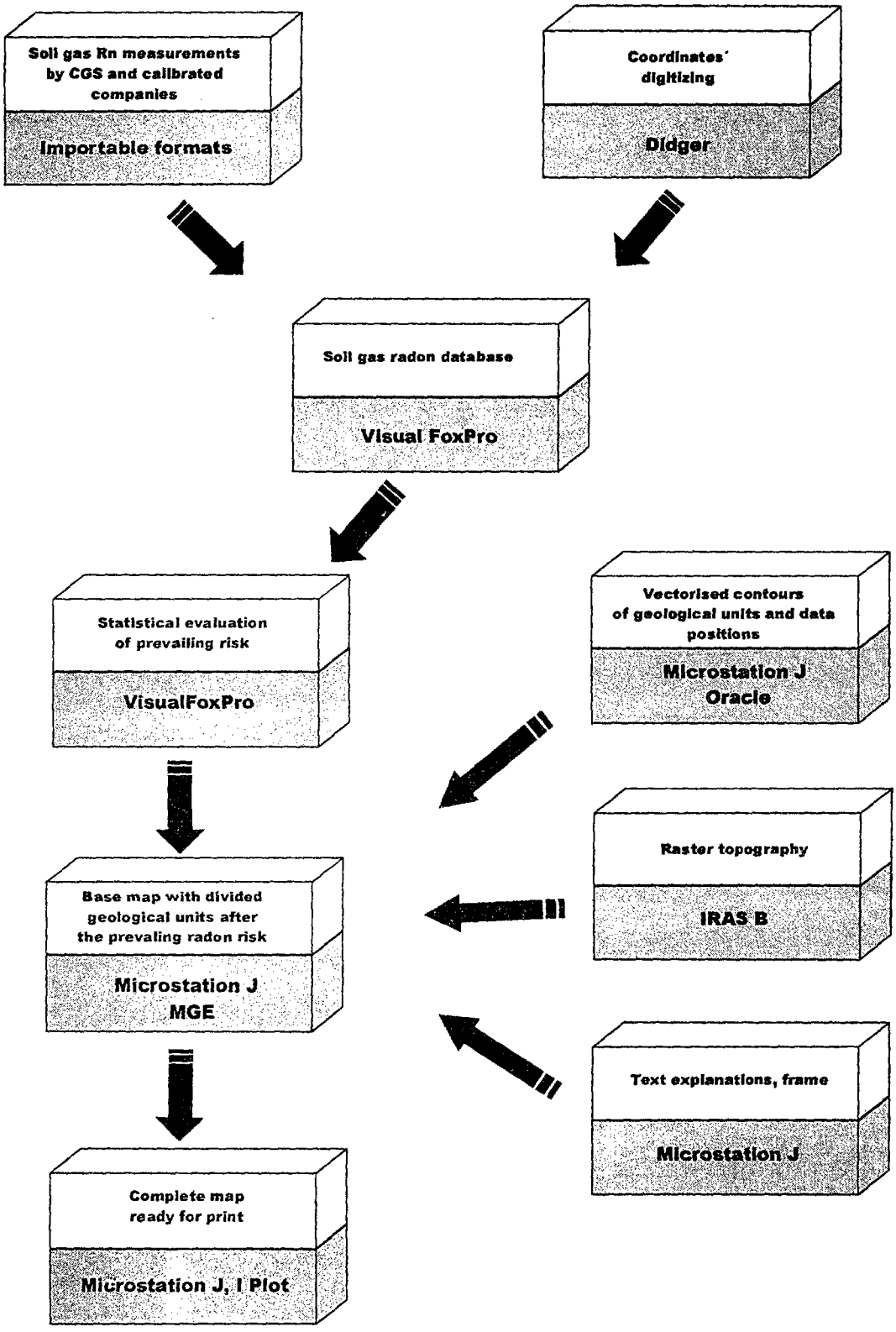


Fig. 3 - The flowchart diagram of creation of radon risk maps on a scale 1 : 50 000

In 1999 16 radon risk maps on a scale 1 : 50 000 covered the area of Třebíč syenite body and Central Moldanubian pluton . These maps are available in digital and printed form. In 2000 the mapping area is extended to granitic bodies of Central Bohemian pluton (westward), Železné Hory pluton (northward) and Brno massif (eastward) – see fig. 4. An example of the section of radon risk map is given in fig. 5.

Testing the reliability of radon risk maps

The radon risk maps serve preferably for determining the level of potential radon release from bedrock. However, the radon entry into existing houses is strongly influenced by the building quality of the house. As the results from radon risk mapping should help to suggest the protective measures for newly built houses, the reliability of maps must be tested by comparing the radon risk categorization based on geology to real indoor radon values.

Until now, the state Bureau of Nuclear Safety has collected the indoor data in the database containing more than 100 000 measurements. From this database 464 municipalities where more than 30% of dwellings were measured, were selected. The statistical processing led to dividing the municipalities into three subsets – those where < 1%, 1 – 10% and > 10% of houses are expected to exceed the action level 200 $Bq.m^{-3}$ EEC. According to soil gas radon classification, the prevailing category of radon risk from bedrock was attached for all municipalities after the existing radon risk maps on a scale 1 : 200 000 . The results of this comparison are given in fig. 6. It is obvious, that approximately in 75% cases the indoor values correspond to the predicted level of radon risk from bedrock. The remaining 25% of over- or underestimation of radon risk is caused mainly by the unconsidered building characteristics of houses or differences between regional and local geology. The data set of 464 municipalities covers various types of bedrock. The large scale comparison has proven that with a certain reliability the information obtained from regional radon risk maps can select the areas, where enhanced indoor radon values could be detected.

The detailed scale comparison was performed in the municipalities situated on the granitic and crystalline bedrock in the southern part of Central Moldanubian pluton. The bedrock in the cadastres of the villages was considered after the detailed radon risk maps on a scale 1 : 50 000. For each cadastre, the prevailing radon risk category (comprising the substantial area of intravilan) and presence of other categories in the intravilan were compared to geometric mean of indoor radon values . As seen from fig. 7, the geologically predicted high radon risk areas prevail in municipalities where more than 10 % of houses are expected to exceed 200 $Bq.m^{-3}$ (which corresponds to geometric mean from indoor measurements equal to 90 $Bq.m^{-3}$ EEC).

Future aims in radon risk mapping

In 2000, 56 map sheets of radon risk maps on a scale 1 : 50 000 will be finished from the total 214 map sheets. The radon risk mapping programme should cover the rest of the state territory within next years as a basis for more sophisticated variations of radon risk maps. . The plotter-printed maps are archived at the Czech Geological Survey and the State Bureau of Nuclear

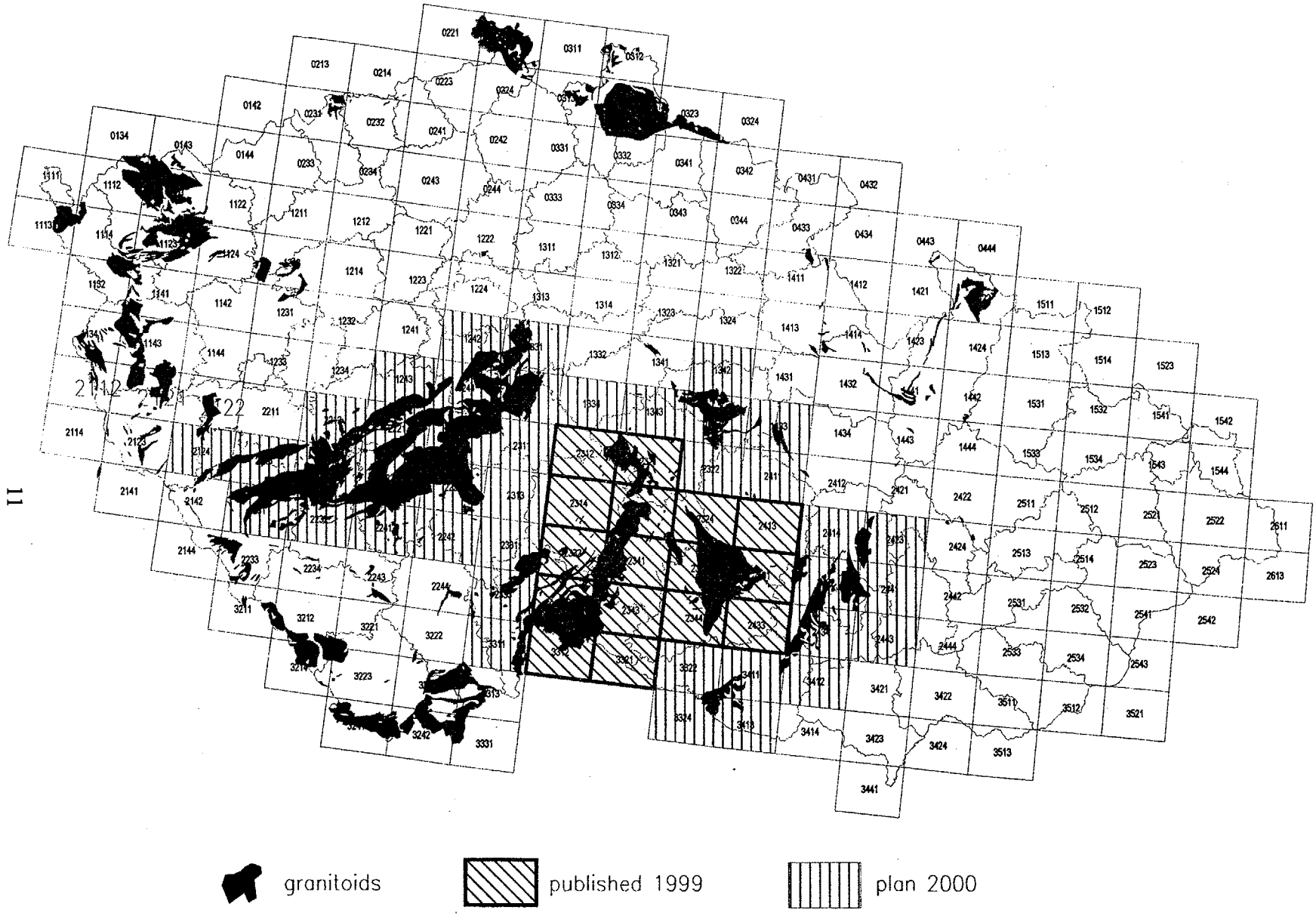
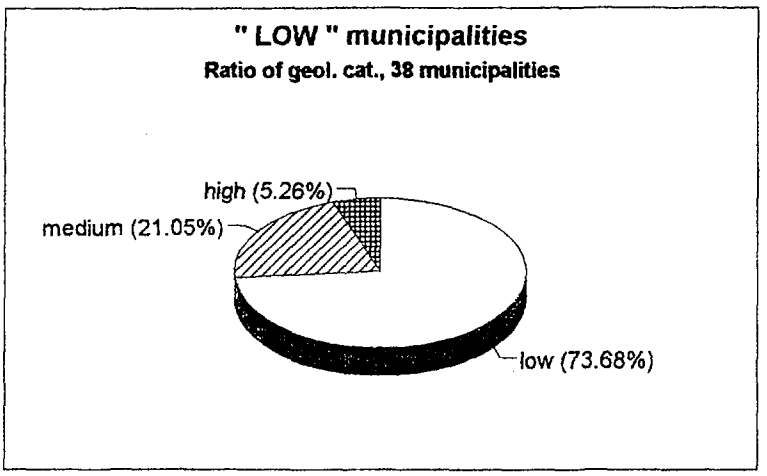
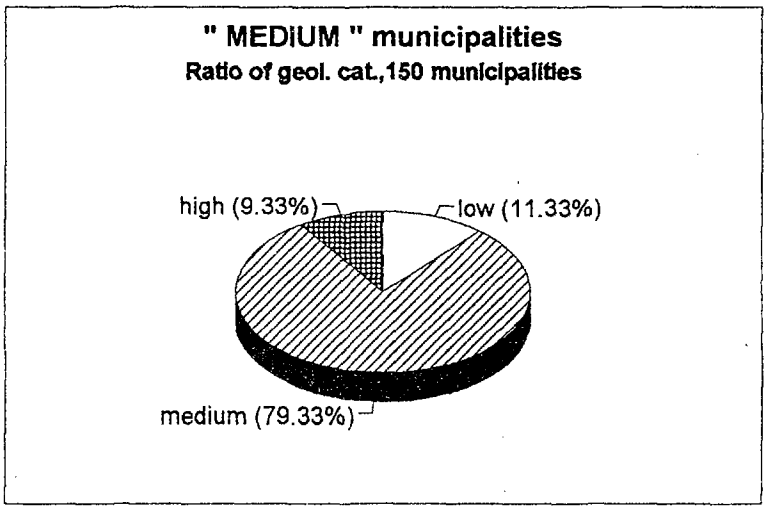


Fig. 4 – The coverage of the state territory by radon risk maps 1 : 50 000

Fig. 5 – The section of radon risk map 1 : 50 000 (area of granits, paragneisses, Quaternary sediments)





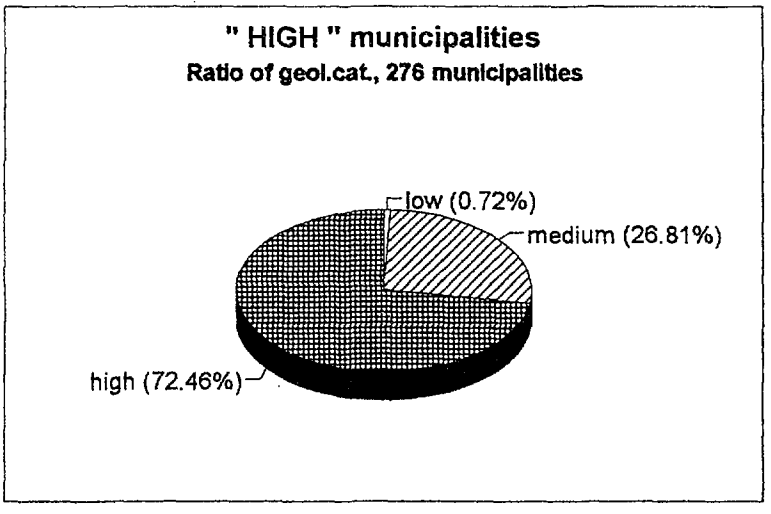


Fig. 6 - The comparison of indoor radon values and geologically determined radon risk

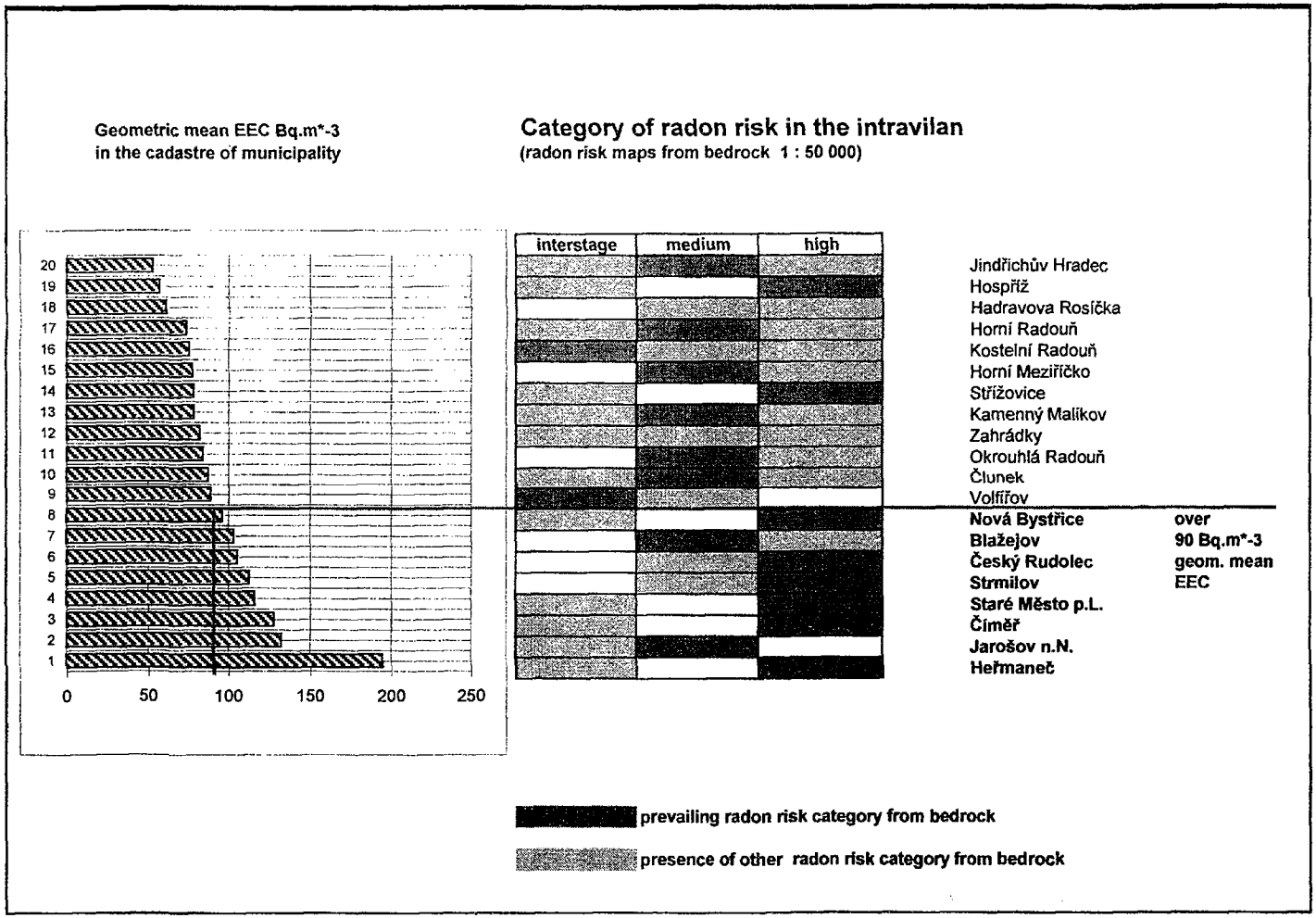


Fig. 7 - The comparison of mean indoor radon (EEC) with radon risk from bedrock in South-Bohemian municipalities situated on the crystalline and granitic bedrock

Safety. These maps are available for public and institutions dealing with the radon programme after order. In preparation there is a presentation of radon risk maps in the digital form on the CD, including the GIS approach to source data files.

The above mentioned radon risk maps on a scale 1 : 50 000 are based on the geological prediction of radon release from bedrock. The future trend demands for relating the data from existing indoor radon database of the State Bureau of Nuclear Safety (until now more than 100 000 houses were measured) with the geological database and the building characteristics of the houses. This connection needs to obtain the coordinates of particular houses, which will be possible after finishing the state cartographic programme of vectorized maps on a scale 1 : 10 000. Inspiring approaches in radon risk mapping from many countries are widely known among the radon geologists, therefore we do not include the references.