International Cartographic Association
Association Cartographique Internationale

Real and Virtual maps conception in web mapping: a case of cartographic support for geological exploration in Andaman deep water basin

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Abstract: The current task of cartographic support for geological exploration and the oil and gas industry is to meet the needs for rapid access to spatial data by specialists. The preparation of specialized data for publication in interactive web maps involves a number of technical issues. Some of them are explored in detail in case of a cartographic support for a cameral processing and interpretation of geological, geophysical and other geoscientific data in Andaman deep water basin. The points highlighted here are in fact a reflection of the role of interactive web maps, regardless of the thematic content, in the development of the Real and Virtual maps concept. The experimental work presented in this article illustrates most of the R/V transformations first developed by H. Moellering in early 1980s. Solving the operations for transformations between real maps, interactive maps, initial (raw) thematic data and cartographic databases will help enrich cartography with new methods of creating and using data, expanding and adapting the communicative conception of cartography to modern realities. An example of the web map developed also shows how the cartographer can simplify the work of professionals in other sectors, their communication with each other through the map language and its web representations. The use of web maps in the poorly studied Andaman deep water basin shows how web maps can contribute to the quality implementation of government programs for increasing exploration and the subsequent development of mineral resources.

Keywords: Andaman deep water, Cartographic support, Data preparation, Real and Virtual maps, Web maps

1. Introduction

Meeting the needs of the geological exploration and oil and gas industry for rapid access to spatial data is an urgent challenge for modern thematic cartography. The development of geo-information and web-based solutions for publishing various geodata simplifies the complex analysis of information. This is particularly important for carrying out a cameral processing and interpretation (PI) of geological and geophysical data (G&G). The results of this stage of geological exploration help to clarify the geological structure of the earth's surface, to identify hydrocarbon prospects in certain regions of the world, and to determine the objectives for drilling and subsequent exploitation of the discovered fields. In such studies it is important to take advantage of the strong sides of modern software triangle: G&G software, GIS and web-based technologies.

In this case the advantages of using web technologies as a new form for access to data are clear: the user gets an interactive environment for view and spatial analysis of all the data (without initial GIS skills) that is accumulated during the cameral PI of G&G data. No time is wasted comparing all the data to solve a routine issue such as “where is the current study area in relation to all the available data” in the interactive web maps.

Meanwhile, an interactive web map, regardless of its thematic content, is a directly visible mapping image on the screen of a device (computer, laptop, mobile device, etc.). Thus, the web map phenomenon can be analyzed as one of the representations of the virtual map in the concept of Real and Virtual maps created by Harold Moellering in early 1980s. Moreover, as we will see further, the issues of data preparation for publication in interactive web maps are in fact well suited to the known transformations between Real and Virtual Maps (R/V).

Hence, the aim of the current paper is to highlight the practical issues of preparing G&G data for publication in a web map as well as the conceptual issues of using web maps as a communication channel of information. The author expects that the solutions presented will be a contribution not only to the expansion of the cartographic support of geological exploration, but also in the general scientific preparation of interactive web maps, regardless of their subject matter.

2. Web mapping in Real and Virtual maps concept

The Real and Virtual Maps concept was first described by Moellering in the late 1970s and early 1980s as an answer for Joel Morrison' “public call to expand the concept of what constitutes a map” (Moellering, 2007). The concept provides a description of 12 transformations between Real maps (R) and three classes of Virtual maps (V_1, V_2, V_3) as well as 4 transformations inside highlighted forms of map data representation. Tim Trainor pointed out in

Proceedings of the International Cartographic Association, 5, 13, 2023.
31st International Cartographic Conference (ICC 2023), 13–18 August 2023, Cape Town, South Africa. This contribution underwent single-blind peer review based on submitted abstracts. https://doi.org/10.5194/ica-proc-5-13-2023 |

2001 that "generally, while dividing the examples into classes continues to hold true, increases in functionality, variability and flexibility warrant further investigation into classifying new forms and uses of cartography" (Trainor, 2011).

Taking into account the development of web mapping, the author considers it logical to define interactive web maps as a typical example of V_1 class of Virtual maps. It will allow us to consider key transformations with other classes, under which we understand the following objects:

- R is the map itself, produced according to traditional cartographic methods,
- V_1 is the interactive web map,
- V_2 is an initial (raw) data in specialized formats,
- V_3 are the processed data in form of digital models, local and remote server cartographic databases (including distributed via OGC standards).

A further detailed review will focus on the data handling in the development of interactive web maps for cartographic support of geological exploration. Practical examples will illustrate most of the R/V transformations and once again will show that R and V_1 characterize the form of cartographic data visualization and V_2, V_3 represent the form of coordinate referenced data storage.

3. Characteristics of the interactive web map under research

The cartographic support is based on a comprehensive geoinformation approach to collecting, processing and providing access to geodata and cartographic materials through GIS and web technologies (Loginov, 2022b). The interactive web map has been prepared according to the universal methodology presented in (Loginov, 2021). Open software was used to create the web service: DBMS PostgreSQL with PostGIS extension and JavaScript library Leaflet. The client part is a PHP-file of the web-page markup, formed on the basis of HTML5, CSS3 and JavaScript. The server part is made by means of Apache HTTP Server.

The target audience for interactive web map under research is a working group of geologists and geophysicists. The purpose of the web map is to provide rapid access and use a set of external and internal geo-referenced G&G data for study tasks. The main work was carried out during cartographic support for the cameral PI of seismic data first time obtained in Andaman deep water basin. The region is poorly explored and among the priority areas, where the Ministry of Petroleum and Natural Gas of India has been performing the National Seismic Program (NSP) since 2016. The NSP aims to improve the country's geophysical survey coverage of all sedimentary basins (India's hydrocarbon outlook, 2021).

Author led cartographic support for PI of 2D seismic data acquired from the following sedimentary basins with different degrees of hydrocarbon resource maturity: Cambay, Kutch, Saurashtra, Vindhyan, Deccan Syneclise, Bhima, Kaladgi, Pranhita-Godavari (Loginov, 2022a). The current new data will help expand the study of the Andaman deep water basin within the Exclusive Economic Zone (EEZ), identify structural, stratigraphic objects and reservoir distribution, clarify oil and gas prospects.

4. G&G data preparation operations in the context of R/V transformations

The data set of the interactive web map under research is made up from several classes of G&G and geographical data. Preparation for publication of these data will be discussed further and accompanied with R/V transformations issues.

4.1 Geophysical study data

Geophysical study is a dataset which characterizes area of interest (study area) location and coverage by current and previous surveys have done by different geophysical methods (gravity, magnetic, seismic survey, etc.). It is a main content element of cameral PI and, of course, cartographic products including interactive web maps. Let's talk about presentation of this information.

Boundaries are a key element of content because they limit the area of interest and influence the choice of minimum scale, central map point, etc. As a rule, boundaries relate to spatial coverage of geophysical survey, but sometimes to a licensed subsoil area or a separate part of sedimentary basins have to be studied. In our case, the study area relate to several licensed subsoil areas located on either side of the Andaman & Nicobar Islands. Geo-coding allows for the creation of polygonal survey boundary objects from tabulated coordinate data contained in the terms of contract ($V_2 \Rightarrow V_3$ transformation). However, often there are no any description about coordinate system the corner points are given. Usually it is WGS 84 (EPSG: 4326), but there may be some exceptions depending on country, where the geophysical survey is carried out. Hence, it is important to know the national coordinate systems that are used.

The next main content elements are a spatial objects ("geo-images") corresponding with G&G initial (raw) data (V_2). All types of G&G data have parts with coordinate data, so it can be possible to prepare geo-images ($V_2 \Rightarrow V_1$). However, again, coordinate system in which the data are recorded is not always specified. As a result, a series of point, line and square localized objects are representing coverage of geophysical surveys in web maps. In our case there are linear and polygonal spatial objects which relates with 2D and 3D seismic data and point objects for drilling data.

Seismic data are stored in specialized formats: *.rps, *.sps for field survey results by receiving and source points, respectively; *.segy for time seismic sections. This data is used to create linear geo-images («seismic lines» layer) as well as point geo-images numbered common depth points («CDP» layer). CDP in traditional seismic acquisition can be very numerous, and their number and distance between depends on the survey

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parameters. In view of the necessity to navigate along each seismic line, CDP pointed geo-images are important and need to be displayed on an interactive web map.

It is important to comply with the requirements for cartographic visualization, namely legibility, plainness, clearness, accuracy and aesthetics (Franges, 2007). However, nowadays there are several problems with simultaneous display of a large number of points using Java libraries. The available clustering methods don't satisfy the requirements, because it is necessary to see CDPs without grouping them together. The optimal solution is to select the first, last and inner points with respect to the scale level of initial web map page. Empirically, a step of 500 CDP for scale level 9 has been identified in our case, which corresponds to 1:1,000,000 map scales. With this step, points are readable and not overlapping, which provides a clear navigation through interactive web map window and the process of reading map itself (V_1 => V_1).

Another pointed geo-image is related to borehole (well) data. It is important to know where the well data are located in relation to seismic sections in order to perform a reasonable stratigraphic referencing (well-tie) and subsequent correlation of seismic reflectors and different seismofacial complexes. Coordinate information is contained in both well completion reports and well logs (*.las). When geo-coding it has to be faced with the fact that the latitude/longitudes coordinates are given in whole seconds, or with two or three decimal places. It is optimal when coordinates are represented in both geographic (GCS) and projected coordinate systems (PCS) and their parameters are also described, so geo-coding errors can be avoided. However, PCS parameters are often not available due to the old age of well logging surveys. In case of Andaman deep water basin, author faced with the fact that in one of the well completion reports of 1988, the GCS and PCS coordinates were indicated, but without any description of the parameters (only a simple projection name "Lambert"). Experimentally, it was found that the PCS Kalianpur_1975_UTM_Zone_46N (EPSG: 24346) is matched with data.

This case highlights once again the difficulties of using old data that were obtained in the now unused coordinate system. This situation is typical for many countries around the world (e.g. see Idrizi, 2019). In India, this problem arose when a major conversion of data from the Indian Grid (based on Lambert Conformal Conic projection and Indian Grid system) to UTM WGS84 was initiated in 2005 under the National Map Policy. Nevertheless, a case that the author had to investigate in 2018 shows that the continued use of multiple coordinate systems (transition period) can lead to unfortunate consequences already at the design stage of an survey network of national importance (Loginov, 2022a). For this reason, care must be taken when geo-coding any survey coordinates data.

It is need to say that well geo-images not only serve as a navigational reference, but also can be a means to access documents through web map page. Current interactive web map implements the possibility of going to the data repository via a link contained in the context tooltip that appears when you click on a wells-associated point. In this way, well completion reports and other documentation can be explored through the web browser (V_1 => V_2), if the plug-ins required opening the relevant formats are available.

Above mentioned layers characterize the study area in terms of completeness of geophysical study. At the same time official study map in raster formats can be uploading into web map. In our case a study map available on the Directorate General of Hydrocarbons official website was geo-referenced, divided into tiles and published on the own web map. An analysis of this map can help to decide if additional 3D, 2D and well data are needed to get a more complete overview and e.g. to clarify the correlation of seismic horizons.

4.2 Geographical data

Most of the G&G web services use global geographical data from main resources (e.g. volunteered geographic information by OpenStreetMap, remote sensing data by Google, Bing, ESRI, etc.) as a background, or so called base map. Technically, base maps connection comes down to describing access to XYZ tiles or OGC-services in web map page code. Thus, the process of accessing remote databases and similar data sources through web map is V_1 => V_3.

In our case (marine study area) it is necessary to use as base map either bathymetry data or a remote sensing data that shows underwater landforms. Both versions have been uploaded to our interactive web map (Figure 1). With these resources, the user can observe how the main tectonic elements that are visible at the surface are related to the seismic pattern observed on the time seismic sections. In our case geophysicists have been able to refine the position of Andaman offshore targets such as Alcock Rise, Sewell Rise, Invisible Bank, Barren Ridge, etc.

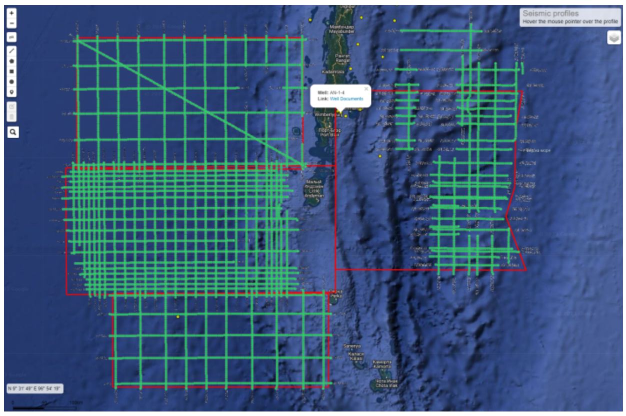

Figure 1. Interactive web map window with remote sensing data as a base map and survey network data

Of course, the above mentioned data can be uploaded to the web map not only in the form of links to remote databases. For example, GEBCO can be uploading as a digital elevation model to estimate water depths (V_1 => V_3) and use it when setting objectives for deep drilling of potentially promising targets, taking into account the technical capabilities of modern offshore drilling technologies. As far as remote sensing data, it is the best source of geographical information, especially in the onshore. However, the availability of a large number of satellite programs makes it possible to use satellite imagery not only as base maps, but also to perform additional geoscientific data analysis with seismic survey data. In particular, radar and multispectral imageries can be used to identify oil seepages on the water surface as the oil and gas presence factor (Mitra, et al, 2013). The results of using Sentinel-2 images to solve such problem will be published by the author in the next articles.

4.3 Topographic maps

The current study area is offshore, and of course the use of topographic maps is out of the question. Nevertheless, the general use of topographic maps as a base maps or a separate layer for interactive web map for cartographic support should be described.

Official topographic maps source of the Republic of India is the Survey of India (SoI), the country's main mapping agency. After release of the National Map Policy 2005 and latest "Guidelines on Geospatial Data-2021" (and before National Geospatial Policy-2022 published in the end of 2022) significant changes have happened on the acquisition and production of geospatial data and services, including maps. The changes are intended to enhance the ability of Indian organizations to freely publish, distribute, update and produce maps/geospatial data of any spatial accuracy. As a result, 1:50,000 Open Series Map sheets are available to Indian citizens through SoI's official website free of charge in *.pdf format for the entire country, except for areas falling under the Restricted Area category. These data are sufficient for area reconnaissance, where the field geophysical surveys will plan. Also it is great tool for comparing the position of ground seismic lines and/or individual geophysical survey points with the interferences and gaps observed in the seismograms during data processing (Loginov, 2022a) and for other tasks.

The decision to include topographic maps in the interactive map should be made based on the coverage schemes which show the relevance of each topographic map sheet ($R \Rightarrow V_1$). The author has developed a cartogram (Figure 2), which allows convenient visualization of the reference data that is available in the notes to the Open Series Map sheets. Map sheet notes has information about years of sheet creation, content update, production of original map and type of survey that was used as the basis for the sheet. The analysis of the resulting cartogram for the Andaman & Nicobar Islands state territory showed that 70% of the 41 available online Open Series Map sheets were created in digital form in 2015. Another 24% were the most recent ones converted to digital form in 2019. Generally, sheets are based on 1966-1969 data (80% of the sheets) with updating for major details in 2003-2006.

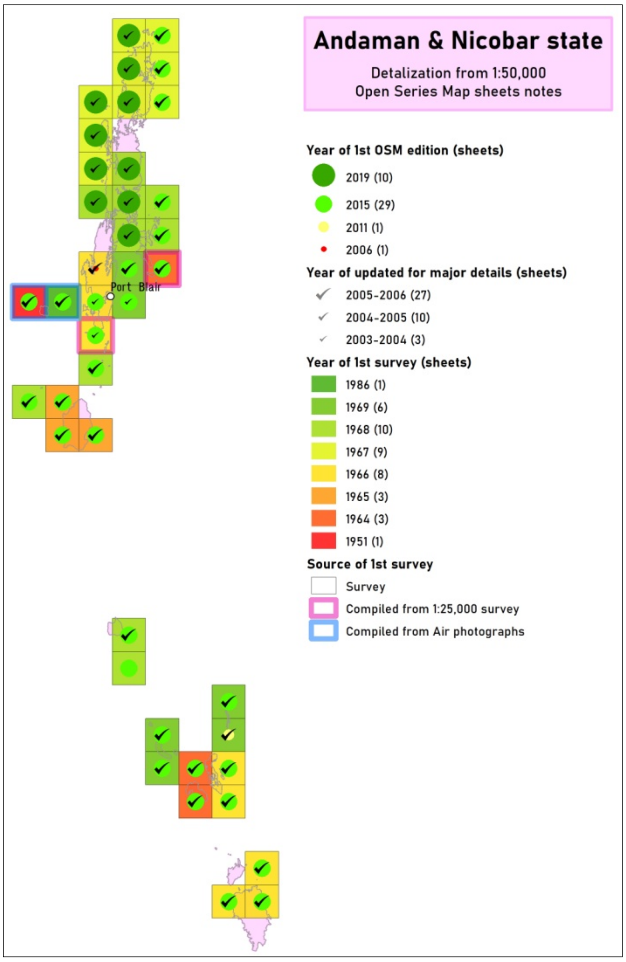

Figure 2. Cartogram of topographic study by 1:50,000 scale Open Series Map sheets for Andaman & Nicobar state

Map sheets also contain explanatory notes about geographical features that require special attention when navigating the area depicted (e.g. prevailing landscapes, accessibility and settlement conditions that cannot be transmitted through conventional signs and their combinations). Author analyzed notes on available map sheets and correlated it with a content elements group. As a result of frequency analysis, it was determined that 40% of notes are related to bathymetry (e.g. "high water line and related features, after the Tsunami of 2004, have not been updated" note), 27% for map creation solutions ("this sheet has been compiled from 1:25,000 scale survey"), as well as 12% for vegetation ("average heights of trees in jungle is 30 meters") and 11% for relief ("the information regarding rocks situated in the sea in this sheet is not complete"). The correlation analysis between the year of publication and number of notes on map sheet has a significant correlation ($r=0.52$), which may indicate that notes are becoming a full part of the mapping process in the production of Indian open-use topographic maps.

The cartogram developed by the author for visualization of reference information ($R \Rightarrow R$) can be used for reconstructing the history of topographic surveying within the study area. It will be a good mean for further analysis not only Indian Open Series Map sheets, but also for use national topographic maps. Especially it is need due to that use of national multiscale base maps is becoming more widespread, depending on the level of state cartography and possibility of publishing these data on particular interactive web maps.

4.4 Geophysical maps

Geophysical maps are an irreplaceable source of information used in cameral PI. They characterize the spatial distribution of the geophysical fields' parameters and need for comparing with the geological situation in the study area. In relation to offshore the use of such data allows clarifying tectonic zoning, position of the main structural-geological elements, faults, zoning of the territory according to the type of the earth's crust structure, detection of large areas of increased thickness of the sedimentary cover, etc.

Preparation of geophysical maps for publication in web map depends on its presentation form. It has been experienced that using digital models of the geophysical field (as a result $V_2 \Rightarrow V_3$ transformation) with the possibility of determining a parameter value at each point when interactively accessing via web map ($V_1 \Rightarrow V_3$) is an excessive option. Geophysicists are more likely to use these data in specialized software because operations can be performed there (for example, calculating the vertical and horizontal gradient of the gravity field and the local component of the magnetic field). For this reason, it is a good practice to publish tiled raster geophysical maps. By visual analyze of geophysical maps, it is possible to provide general answers to questions about the continentality of the crust, to identify subduction zones, to trace lineaments, delineate boundaries of different level tectonic blocks and generally accompany work on correlation of seismic horizons. User can also create his own layer combinations ($V_1 \Rightarrow V_1$), such as overlaying seismic lines on top of a geophysical map (Figure 3). If features can be found on the seismic data, further conclusions about their prospectivity can be reached with different geophysical survey methods data.

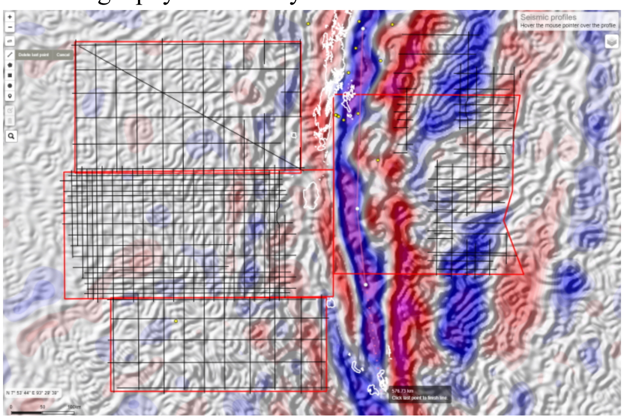

Figure 3. Interactive web map window with overlapping survey network data and a composite of the local component of gravity field and its vertical gradient (XGM2019e model by Zingerle, 2020)

4.5 Geological maps

The second irreplaceable source of information is geological maps. They are necessary for traditional tasks, such as clarifying geological structure, studying lithology and stratigraphy, tectonic development, structural interpretation, paleotectonics, sources and reservoirs regional distribution, hydrocarbons prospects identification, geological risk assessment and other tasks.

When preparing geological data for own interactive web maps, priority is given to major cartographic products (e.g. regional tectonic maps) that have been compiled as a result of a long-term research by scientific teams (Figure 4). However, the years of map publication should be taken into account, as the data on such maps are based tends to become outdated. The cartographic support for G&G PI with new data is itself helpful in clarifying proven concepts regarding the tectonic structure and region oil and gas potential.

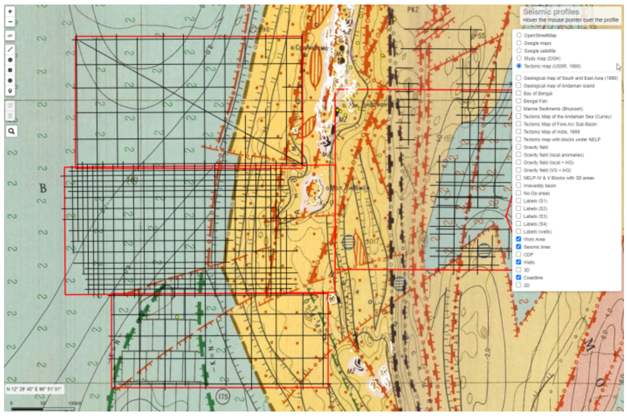

Figure 4. Comparing survey network data with Fault tectonics map of the South of Asia with 1:5,000,000 scale (VNIIzarubezhgeologia, 1980) used as a base map

Old geological maps and other raster data can be used as a base maps, if they are geo-referenced correctly ($R \Rightarrow V_2$). This is achieved, in part, by having information about the projection in which the map was made. In many cases such information is not available, so the cartographer has to determine the basic parameters of the projection by such typical features as curvature of the grid lines, distance between meridians and parallels, the presence of the pole, etc. The modern studies on the automated determination of the published map projection (Zagrebin, 2016), the optimal projection of the own map (Gosling, Symeonakis, 2020), etc., can be helpful.

Of course, more detailed geological maps are needed to use in web maps for cartographic support of geological exploration. In the process of reviewing knowledge about geology in study area, the specialists look at numerous scientific papers that include different kinds of geological maps and schemes. These data come to the cartographer for publication on the web to share with other professionals involved in cameral PI works. The cartographic support is aimed towards the rapid digitizing ($R \Rightarrow V_3$) and publication of these figures together with other data. In this way, users become participants in defining data for interactive web map layers ($R \Rightarrow V_1$).

However, only a few of cartographic figures from papers are eligible for use, because each map is different in scale, spatial coverage, design principles, image resolution, etc. For example, when geo-referencing maps from papers, the cartographer often comes up against the lack of spatial tic marks, graticule of latitudes and longitudes. There are also schematic representations of landmarks, such as settlements, watercourses and even administrative boundaries. Experimental work has confirmed the conclusions of the research papers about analysis of information content and quality of maps published in articles in geoscientific journals (Pal, Albert, 2021) and in PhD (Coetzee, et al, 2022). Researchers have identified that features such as settlements, hydrography and road networks are rarely included in geological and especially geophysical maps which are compiled by the authors of the articles. This is mainly due to the subject matter of the maps, but it is also due to the fact that geophysicists and geologists produce these maps and charts themselves without any help of cartographer or/and without GIS skills. Thereby the cartographer should take all these imperfections into account when geo-referencing paper figures with help GIS tools and publishing particular figures in web map. Incorrect geo-referencing can lead to false assumptions about geological exploration. Nevertheless, if this is the chart/scheme/map that experts need, however wrong it may be from the professional cartographer's point of view, the maximum should be extracted from the minimum.

5. Results and discussion

All of the data discussed above has become the main content of an interactive web map that has been used by geologists and geophysicists during the PI of new seismic data in Andaman deep water basin. Web map allowed all collected data to be accumulated in a single geospatial environment, collaborative analysis, and data sharing with other members of the cameral team. It was also useful for both internal and external meetings, up to and including project results defense. Another advantage is that there is no need to install specialized software – the interactive web map is accessible via a simple browser both on a desktop computer and a mobile device in field (Figure 5). The only requirement for the developer is to think about adaptive design issues so that the web map can be equally displayed correctly on different devices.

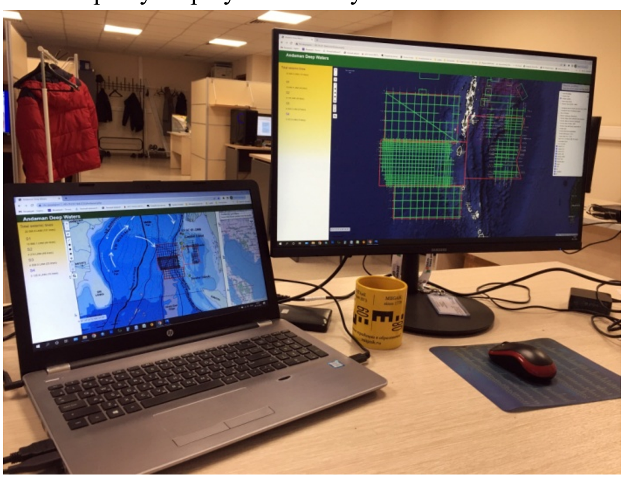

Figure 5. Interactive web map displayed on different screens during the daily works (top) and geological field trip (bottom)

The issues addressed in preparing data for publication in a thematic web map revealed most of the R/V transformations that are actually inherent in any interactive web map. Indeed, generating spatial database content from a thematic dataset (V_2 => V_3) is nothing more than transforming raw survey data into database and digital models. The subsequent cartographic visualization is generally a V_1 => V_3 transformation. Moreover, in technical terms, the visualization also represents like a client's request to a database. In this term, a database response to client request is a reverse V_3 => V_1 transformation. In this way, the modern duality of cartographic data visualization becomes apparent. It also reveals itself when a traditional map reading process in web mapping is carried out via interactive user communication through different tools (V_1 => V_1). This includes e.g. changing map extent (moving, zooming), measuring distances and search by attributes. Also through interactive drawing tools and custom tools for downloading *.kml/kmz and creating objects by coordinates it becomes possible to enter data into the database via web map plug-ins (V_1 => V_3).

Functionality of web maps is not limited by requests. It can also assist in the preparation of maps as a result of PI G&G data. However, not everything is clear here either. Indeed, the user can click ‘print’ button, and a picture based on all data uploaded by the cartographer is ready. But this is not always a good solution. First reason is that a map prepared as a screenshot is not a map in the sense of traditional cartography. Of course, it is a V_1 => R transformation, but in this case R it is an R', an intermediate version of real map. Let's agree that figures 1, 3 and 4 in this paper are not maps.

Second reason is that not all maps and charts in the web service are to the scale of an interactive map. In essence, an overview map is just an overview map designed to compare data at a regional level. But if it is studied at a large scale, which corresponds to the spatial coverage of the project data (especially boundaries of the study area), we will see via web map only blurred outlines and symbols (this is also mentioned in (Trainor, 2001) regarding V_3 => R and V_3 => V_3 transformations). Thus, with the apparently simple job of publishing raster

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images, the choice of the optimum scale levels to which the tiles should be cut comes to the fore. The individual approach to each illustration doesn't add time, because it is compensated by not having to tile into typical scale levels. Detailed levels (starting from 10) are not needed for regional maps, thus it is possible to free the machine power involved in the conversion of geo-referenced image to XYZ tiles. Hence, the issue of automated selection of optimal number of scale levels when tiling depending on scale, spatial coverage, resolution and other factors is another promising direction for research.

To sum up, we need to say that interactive web maps as well as a raw specialized data, databases and maps can be present and related to Real and Virtual map concept. An appendix provides a table with examples of each R/V transformation in the context of creating interactive web maps regardless of the final theme. Each R/V transformation actually characterizes quite specific general scientific problems, including the preparation of survey maps, the automated selection of optimal scale levels while preparing tile representations of raster images, content analysis of topographic maps, improving the compilation and design of geoscientific maps published by private specialists in their papers, etc. These are clearly needs that can be addressed for future research.

6. Conclusions

Web map services rightfully hold a special place among modern ways of providing access and user interaction with data which has geospatial characteristics. The example of the developed web service for cartographic support of geological and geophysical research to identify oil and gas prospects of Andaman deep water basin shows how the cartographer can simplify the work and communication of different specialists with the map language. The specific features discussed for the preparation of data on the study area (geophysical study, geographical base maps, remote sensing data, and topographical, geological and geophysical maps) demonstrates on the one hand the multi-aspect of geological exploration, and on the other hand the technical and concept features of geodata publication in a web-based environment.

Of course, the cartographer makes life difficult for himself by offering geologists and geophysicists a new means of communicating and accessing data in addition to or as a replacement for specialized software. But it is also painstaking and creative work of designing a user-friendly web service, producing aesthetically attractive maps. The cartographer's ability to critically evaluate the maps and content of interactive web maps he or she has developed is important here. This work also includes communication with specialists from other sectors with the aim of developing optimal information content of web map or any web service, and searching for cartographic tools which can realize the needs of geologists and geophysicists in solving global tasks such as determining the oil and gas prospects.

Thus, the current review about data preparation for publication in the interactive web maps led to the global conclusion that the cartographic support of G&G surveys should be aimed not only at creating beautiful and scientifically accurate maps but also at improving the culture of GIS work among geologists and geophysicists.

Author's experience might help other cartographers and developers of web services who publish data for informational content of G&G or another thematic web services which are used in internal works of service organizations, state companies, research institutes, etc. The use of web maps in the poorly studied Andaman deep water basin shows how web maps can contribute to the quality implementation of government programs for increasing exploration, the identification and subsequent development of mineral resources, the economic and energy security of world countries. Furthermore, solving the operations for transformations between real maps, interactive web maps, initial raw thematic data and cartographic databases will help enrich cartography with new methods of creating and using data, expanding and adapting the communicative conception of cartography to modern realities.

6.1 Acknowledgements

Author is grateful to the reviewers for their comments, which improved the concept of this article.

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8. Appendix

	R	V_1	V_2	V_3
R =>	Traditional cartography and map use	Selection of source for interactive web map layers after reading hard copy maps and map-contained papers	Scanning of hard copy maps. Geo-referencing of scanning maps	Digitizing
V_1 =>	Printing a screenshot	Interactive web map reading (visual layer analysis). Interactive communication with the web map layers (navigation, zooming, overlaying, etc.).	Access to the raw data storage via clicking spatial objects (“geo-images”) on the web map	Client request to local and remote server database via web map layers. Getting digital model values from a web map. Cartographic visualization of data from databases. Enter/change data layers in databases via interactive web map plug-ins
V_2 =>	Creation of study maps (maps of coverage by surveys). Creating a geo-referenced data catalogue	Creation of geo-images (spatial objects related to survey data). Connecting links to files in specialized formats	Data conversion from one to another specialized formats	Geo-coding. Creation of digital models using data from specialized formats. Supplementing databases with specialized information
V_3 =>	Digital generation of a hard copy map from a digital cartographic database	Database response to a client request	Data export from database into files in specialized formats. Modify a part of data in specialized formats via database (e.g. adding coordinates in local PCS)	Upload/download data/digital models to/from the local/remote database

Table. Some examples of R/V transformation in data preparation for an interactive web maps