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120 years of georesources research in Switzerland: the Swiss Geotechnical Commission (1899–2018)

S. Heuberger[1*], L. Nibourel[1], D. Fulda[1] and M. G. C. Vernooij[2]

Abstract

Geological surveys have a wide range of tasks for their countries: to map the geology and to assess the georesources potential for metallic ores, industrial minerals, geothermal energy, fossil fuels, aggregates and groundwater. In Europe, most countries founded geological surveys around the mid-nineteenth century in order to create an overview of the geological resources they wanted to exploit. In Switzerland, at that time, the industrial revolution triggered a tremendous demand for infrastructure and energy raw materials. However, no national georesources institution was established when the nation-forming process among the 25 cantons culminated in the foundation of the Swiss Federal State in 1848. The Swiss Geological Survey was founded 138 years later in 1986. How did Switzerland map the country, assess the resource potential and provide fundamental data for land use planning without such an organisation?
This paper elaborates on the evolution of Swiss institutions mandated to study the geological resources, with a focus on the Swiss Geotechnical Commission (SGTK, 1899–2018). Given the low financial resources, no long-term nationwide investigation programs could be implemented. The commission's study program was mainly driven by external societal and political factors. World War I for example reactivated the search for coal which was intensively exploited during those years. Before and during World War II, the focus temporarily shifted to oil and gas exploration. From 1970 onwards, SGTK was involved in several applied research projects and collaborations with various industry partners.
In this paper, we revisit the key turning points in the evolution of the commission's investigation program, including related financial and organisational aspects, and discuss how Switzerland's federalistic structure influenced the geological survey activities. The history of the SGTK represents an exemplification of how a nation managed its geological survey activities, until 1986 in the absence of a geological survey and without large hydrocarbon and metallic ore resources and a corresponding, significant mining industry. The SGTK case also shows that flexible, project-based investigations can be advantageous as they respond to current challenges at short notice. This could to some degree substitute the initial absence of a geological survey, as shown by the numerous SGTK monographs that are key references also 100 years after their publication.

Keywords: Swiss georesources, Raw materials, History of science, 19th–20th century, Applied research, SGTK

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Zusammenfassung

Geologische Landesdienste haben ein breites Aufgabenspektrum: Sie kartieren die Geologie des Landes und evaluieren das Potential der Georessourcen für metallische Erze, Industrieminerale, Zementrohstoffe, Beton-Zuschlagstoffe, geothermische Energie, fossile Brennstoffe und Grundwasser. In Europa gründeten die meisten Länder um die Mitte des 19. Jahrhunderts nationale geologische Landesdienste, um sich einen Überblick über die geologischen Ressourcen zu verschaffen, die sie abbauen und verwenden wollten. In dieser Zeit löste die industrielle Revolution in der Schweiz einen enormen Bedarf an Infrastruktur und Energierohstoffen aus. Als die Nationsbildung durch die 25 Kantone 1848 zur Gründung des Schweizer Bundesstaates führte, gab es noch keine nationale Institution für Georessourcen. Der Schweizerische Geologische Landesdienst, die "Landesgeologie", wurde erst 138 Jahre später, 1986, gegründet. Wie hat die Schweiz ohne eine solche Organisation das Land kartieren, Abschätzungen des Ressourcenpotentials durchführen und Grundlagedaten für die Raumplanung bereitstellen können? Dieser Artikel zeigt die Entwicklung der Schweizer Institutionen auf, die sich der Erforschung der geologischen Ressourcen gewidmet haben, mit Fokus auf der Schweizerischen Geotechnischen Kommission (SGTK, 1899–2018). Aufgrund der geringen finanziellen Mittel konnten keine langfristigen, landesweiten Untersuchungsprogramme durchgeführt werden. Insgesamt wurde der Fokus der Kommission vor allem durch äussere gesellschaftliche und politische Faktoren bestimmt. Der Erste Weltkrieg zum Beispiel reaktivierte die Suche und den Abbau von Kohle. Vor und während des Zweiten Weltkriegs verlagerte sich der Schwerpunkt vorübergehend auf die Öl- und Gasexploration. Nach 1970 gab es keinen klaren Forschungsschwerpunkt mehr, aber die SGTK war an mehreren angewandten Forschungsprogrammen und Kooperationen mit verschiedenen Industriepartnern beteiligt. In diesem Beitrag rekonstruieren wir die Entwicklung des Untersuchungsprogramms der SGTK einschliesslich der damit verbundenen finanziellen und organisatorischen Aspekte und diskutieren den Einfluss der föderalistischen Struktur der Schweiz. Die Geschichte der SGTK stellt ein Beispiel dafür dar, wie eine Nation ihre geologischen Untersuchungsaktivitäten in (anfänglicher) Abwesenheit eines geologischen Landesdienstes und ohne grosse Kohlenwasserstoff- und Metallerz-Vorkommen und einer entsprechend bedeutenden Bergbauindustrie bewältigte. Es zeigt sich auch, dass flexible, projektbezogene Forschung vorteilhaft sein kann, da sie kurzfristig auf aktuelle Herausforderungen reagieren kann. Auf diese Weise konnte die Kommission den anfangs fehlenden geologischen Landesdienst bis zu einem gewissen Grad ersetzen, wie zahlreiche SGTK-Monographien zeigen, die auch 100 Jahre nach ihrem Erscheinen noch wichtige Referenz-Publikationen sind.

Keywords: Schweizer Georessourcen, Rohstoffe, Wissenschaftsgeschichte, 19. & 20. Jahrhundert, angewandte Forschung, SGTK

1 Introduction

National georesources investigations provide geospatial knowledge on critical resources to governments and are generally carried out by national geological surveys. The tasks of these surveys evolved significantly through time and are country-specific. They include (1) mapping the country's geology, (2) assessing the potential for georesources, (3) providing data on surface and groundwater resources and soils and (4) understanding the geological hazards, climate and environmental change (e.g. Hill et al., 2020). In Switzerland, the institutionalised search for geological resources has a long and dynamic history. Swiss georesources first became a major national issue during the national exhibitions 1883 in Zurich and 1896 in Geneva (e.g. Duparc, 1896; Gremaud, 1898). This interest was late in contrast to many European countries that founded geological surveys already in the mid-nineteenth century (e.g. Great Britain in 1835, Norway in 1858, France in 1868; e.g. Brianta, 2000; Wellmer & Röhling, 2021). Switzerland did not have a national mining law and the mining industry was comparatively weakly developed, with only local mining of small coal and ore deposits as well as peat, gravel or construction stones. Mining rights were granted, and still are today, by the cantons (member states of the Swiss Confederation). This seems to be an important factor why there was no national geological survey established at that time. Educational institutions or professional associations for applied georesources research did not exist yet (Gugerli & Speich, 2002, Westermann, 2011). Geologists in Switzerland were mainly focusing on fundamental geoscientific questions such as the formation of the Alps or the Jura mountains (e.g. Escher, 1836, 1846, Escher & Studer, 1839, Studer, 1834, 1851, 1853, Fig. 1). These geologists founded the Swiss Geological Society (*Société géologique Suisse*) in 1882 with its bulletin *Eclogae Geologicae Helvetiae* that released its first publication in 1888 (e.g. Nabholz, 1983; Schaer, 2007).

With the pan-European intensified search for coal after the Franco-Prussian War (1870–1871), the need for a regional, i.e. national surveying of geological resources appeared also in private organisations and some cantons

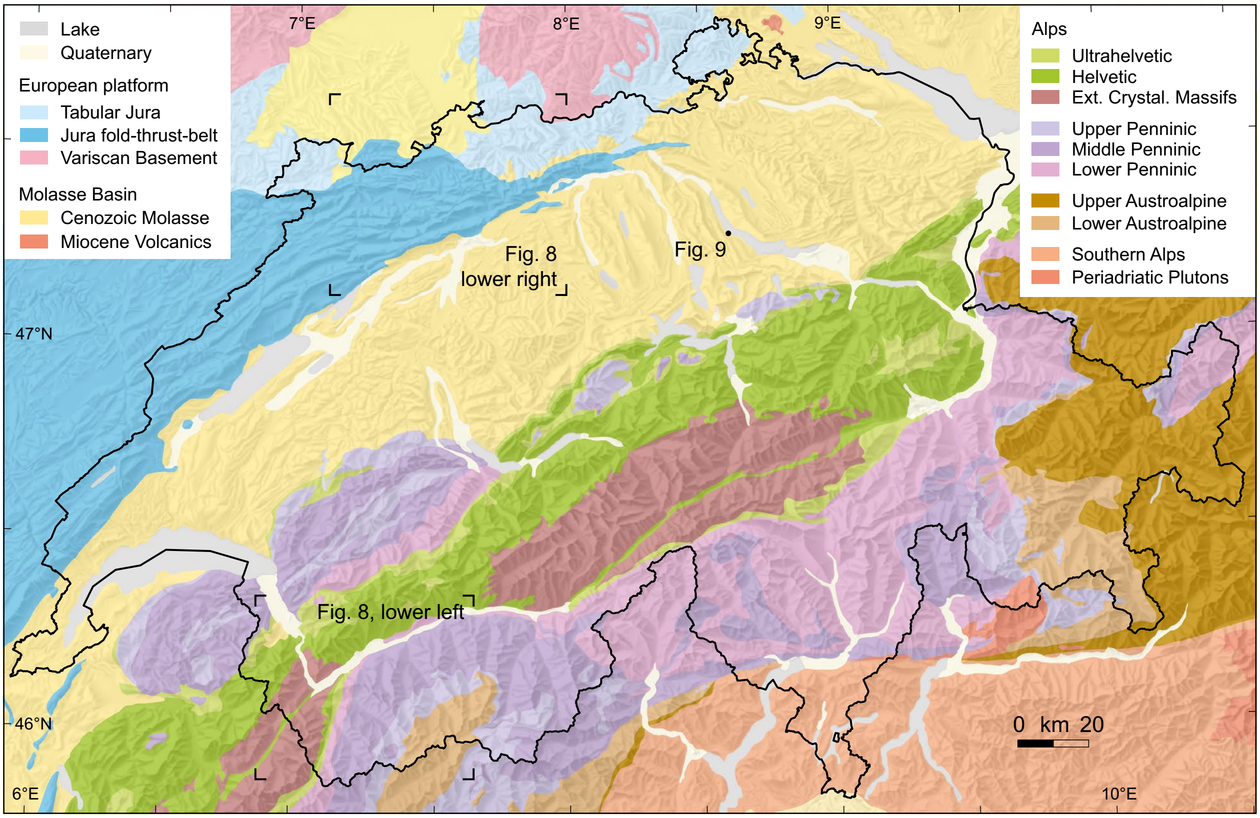

Fig. 1 Tectonic map of Switzerland illustrating the main geological domains of the European Platform, the Molasse Basin and the Alps. Note that "Cenozoic Molasse" polygons include the Cenozoic foreland basin units of the North-Alpine Molasse Basin, the Upper Rhine Graben and of the Po Basin. The Quaternary is displayed only along the main valleys

of Switzerland. At the end of the nineteenth century, the Swiss Federal Council originated the Swiss Geotechnical Commission (*Schweizerische Geotechnische Kommission* SGTK, Fig. 2) as an expert commission of the Swiss Society of Natural Sciences (*Schweizerische Naturforschende Gesellschaft* SNG, today the *Swiss Academy of Sciences* SCNAT) in 1899 (Fig. 3). This new commission was complementary to the already existing Swiss Geological Commission (*Schweizerische Geologische Kommission* SGK) and represented the first federally organised and sponsored georesources survey institution (e.g. Schaer, 2007).

This paper reviews the 120 years history of the SGTK between 1899 and 2018 and puts its key evolutionary steps into a temporal context. The roles of the Swiss Federation, the Swiss universities and the Swiss industry regarding research on the geological resources of the country are elaborated. What are the key scientific achievements, what remains of the SGTK today, who has taken on its activities, and what can we learn from this evolution of public–private applied research cooperations and georesources research in a country with no hydrocarbon or metal mining industry?

2 From the Dufour Map to the first national georesources map

In the early nineteenth century, prior to the foundation of the Swiss Federation, leading Swiss geologists demanded a precise topographic map covering the entire country to map and illustrate geological findings (Graf, 1896). At that time, there was no funding for nation-wide projects. In 1828, the SNG, namely its member and later professor for mineralogy at the University of Bern Bernhard Studer, initiated the production of a nation-wide topographic map (Aeppli, 1915; Graf, 1896; SNG, 1828). However, only the foundation of the Swiss Federal State in 1848 and the thereby growing demand for a solid topographic planning basis for national and military purposes speeded up this large cartographic project that resulted in the Dufour topographic map (Dufour, 1865). The production of this map lasted from 1832 to 1864 (Graf, 1896). The 25 map sheets at a 1:100′000 scale were published between 1844 and 1864. The cooperation between

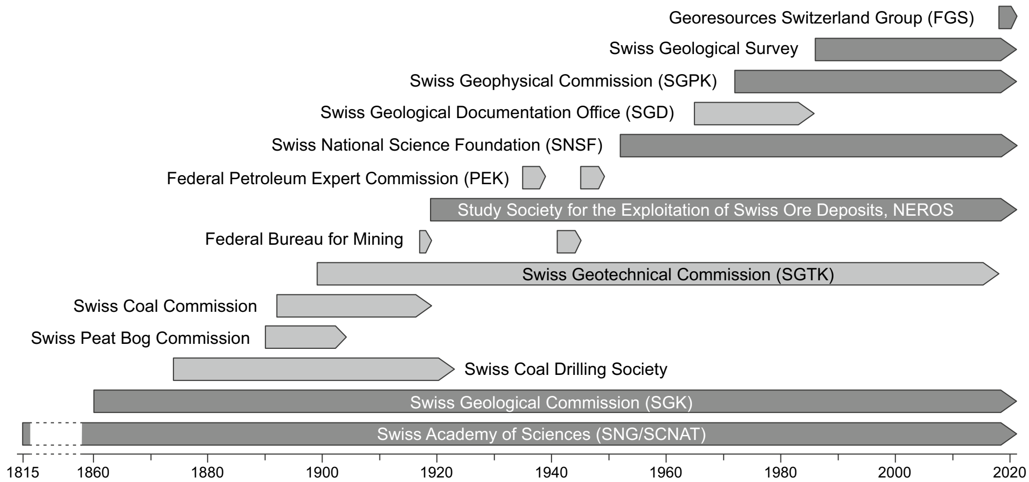

Fig. 2 Chronological overview on the georesources-related Swiss institutions discussed in the text. Arrows in dark grey mark institutions still existing today. Relationships between these institutions are shown in Fig. 3. Note that the term Swiss Geological Survey is used here in a wider sense and includes the survey's predecessor institutions LHG and BWG (see Fig. 3 for details). The abbreviations are derived mostly from the German names of the institutions as following: SNG: Schweizerische Naturforschende Gesellschaft, SCNAT: Akademie der Naturwissenschaften Schweiz (the SNG became the Swiss Academy of Sciences SANW (Schweizerische Akademie der Naturwissenschaften) in 1988, which was renamed into SCNAT in 2004), SGK: Schweizerische Geologische Kommission, SGTK: Schweizerische Geotechnische Kommission, SGPK: Schweizerische Geophysikalische Kommission, PEK: Petroleum-Experten-Kommission, SGD: Schweizerische Geologische Dokumentationsstelle, LHG: Landeshydrologie und -geologie, FGS: Fachgruppe Georessourcen Schweiz, Study Society: Studiengesellschaft für die Nutzbarmachung der schweizerischen Erzlagerstätten, NEROS: Netzwerk Mineralische Rohstoffe Schweiz

the cantons and the newly created federal offices for this purpose represents a landmark nation-forming act and the basis of the emerging central Swiss administration (Gugerli & Speich, 2002).

In 1858, B. Studer stimulated his colleagues in the SNG to make use of the 18 Dufour map sheets available to produce a geological map of the entire country (Rudio & Schröter, 1915; Schaer, 2007; Studer, 1858). To tackle this pioneering mapping project, the SNG founded the Swiss Geological Commission (SGK) in 1860, with a guaranteed subsidy of CHF 3′000 by the Federal Council (Seippel, 1900, Fig. 2). Members were highly renowned geologists from all over Switzerland; prof. A. Escher von der Linth (Zurich), prof. P. Merian (Basel), prof. E. Desor (Neuchâtel), A. Favre (Genève) and prof. B. Studer as president (Bern) (Aeppli, 1915). As a result, the geological map of Switzerland at 1:100′000 scale was published between 1864 and 1887 on the basis of the Dufour map (Aeppli, 1915). It replaced the overview geological maps of Switzerland by Studer (1851–1853) and Studer & Escher (1853).

Towards the end of the nineteenth century, a mineral resources map (1:500′000) of Switzerland, mandated by the Swiss Department of Trade and Agriculture, was presented at the first national exhibition 1883 in Zurich (Streng, 1884, Weber & Brosi, 1883, Fig. 4). This map represents the first comprehensive georesources map of Switzerland. Another landmark work, a comprehensive monograph on Swiss construction materials, including natural stones and binding materials (cement), was presented by Meister et al. (1884). The monograph contains more than 4′000 laboratory test results on the compressive strength of hydraulic binders and natural and artificial building stones, which were carried out at the Swiss Federal Laboratories for Materials Science and Technology Empa (Fig. 3, at that time called *Eidgenössische Anstalt zur Prüfung von Baumaterialien*). The key value of this compilation is that a systematic and normalised testing procedure was implemented to classify the materials at the Switzerland-scale for the first time. This provided a solid basis for the construction industry for selecting the suitable materials and also comparing them to foreign potential alternatives. In addition, this testing project resulted in Switzerland's first standards on uniform nomenclature, classification and testing of building and construction materials (Brosi, 1883; Tetmajer, 1883, 1893). Inspired by the high demand for these products, L. Duparc and co-workers at the University of Geneva produced a new raw material occurrences map with a significantly increased resolution (1:100′000). It included comprehensive explanatory notes and a first collection of corresponding rock samples, presented together with the map (which was never published, Schmidt, 1896) at the 1896 national exhibition in Geneva (Duparc, 1896).

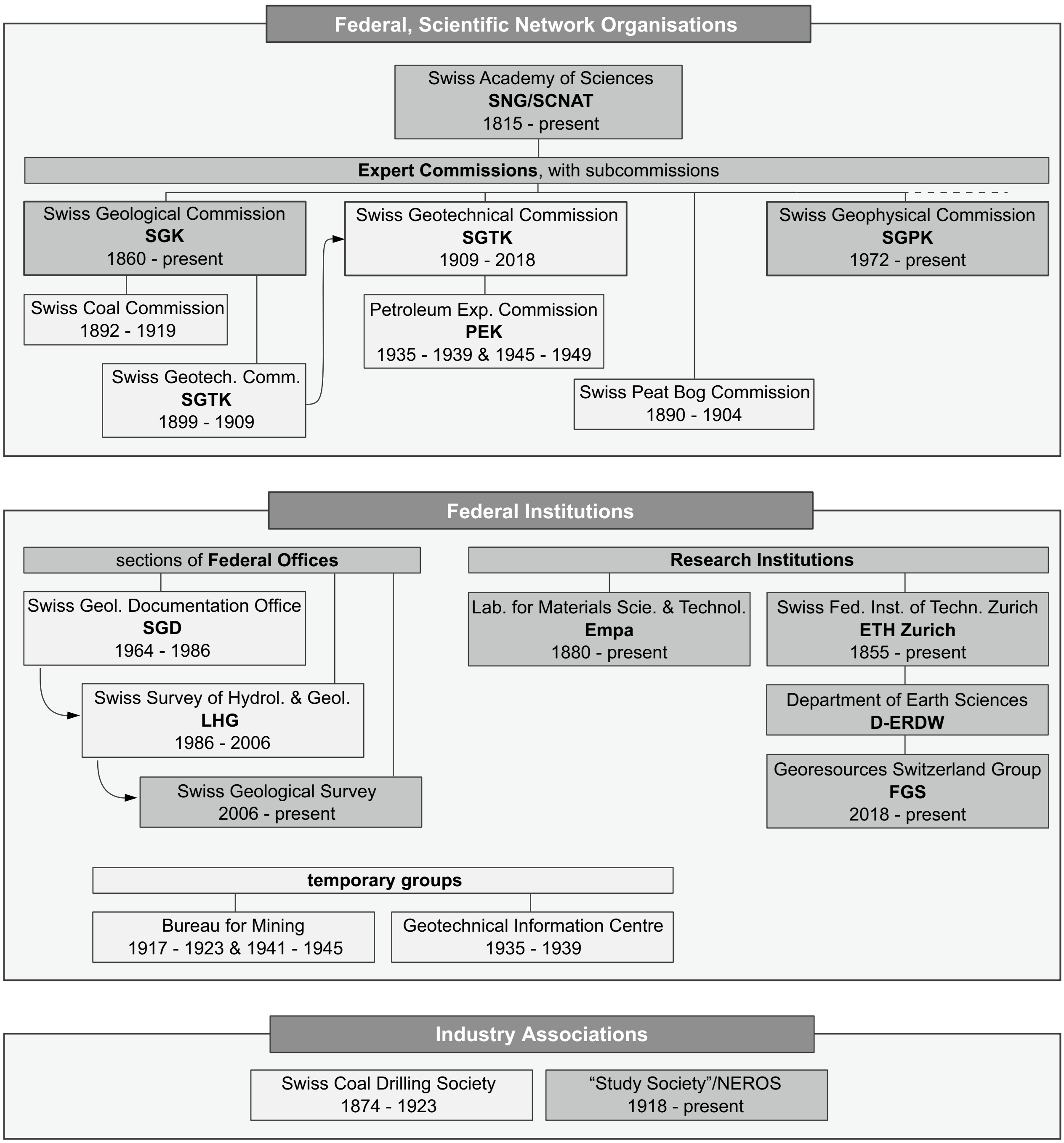

Fig. 3 Organisational diagram of the georesources-related Swiss institutions discussed in the text. The vertical lines between boxes indicate sub-units. For an illustration in chronological order, the full list of the names, abbreviations and colours see Fig. 2. Empa: Eidgenössische Materialprüfungs- und Forschungsanstalt, ETH: Eidgenössische Technische Hochschule Zürich, D-ERDW: Departement Erdwissenschaften. Note that only those Swiss institutions are presented here which are discussed in the text. For an illustration in chronological order and the full list of the names see Fig. 2

These national georesources compilations (versions 1883 and 1896) at least partly, built on existing regional studies on ores and minerals (e.g., Gerlach, 1873; Kenngott, 1866) as well as on cement raw materials (Heim & Jaccard, 1894 in Tetmajer, 1893).

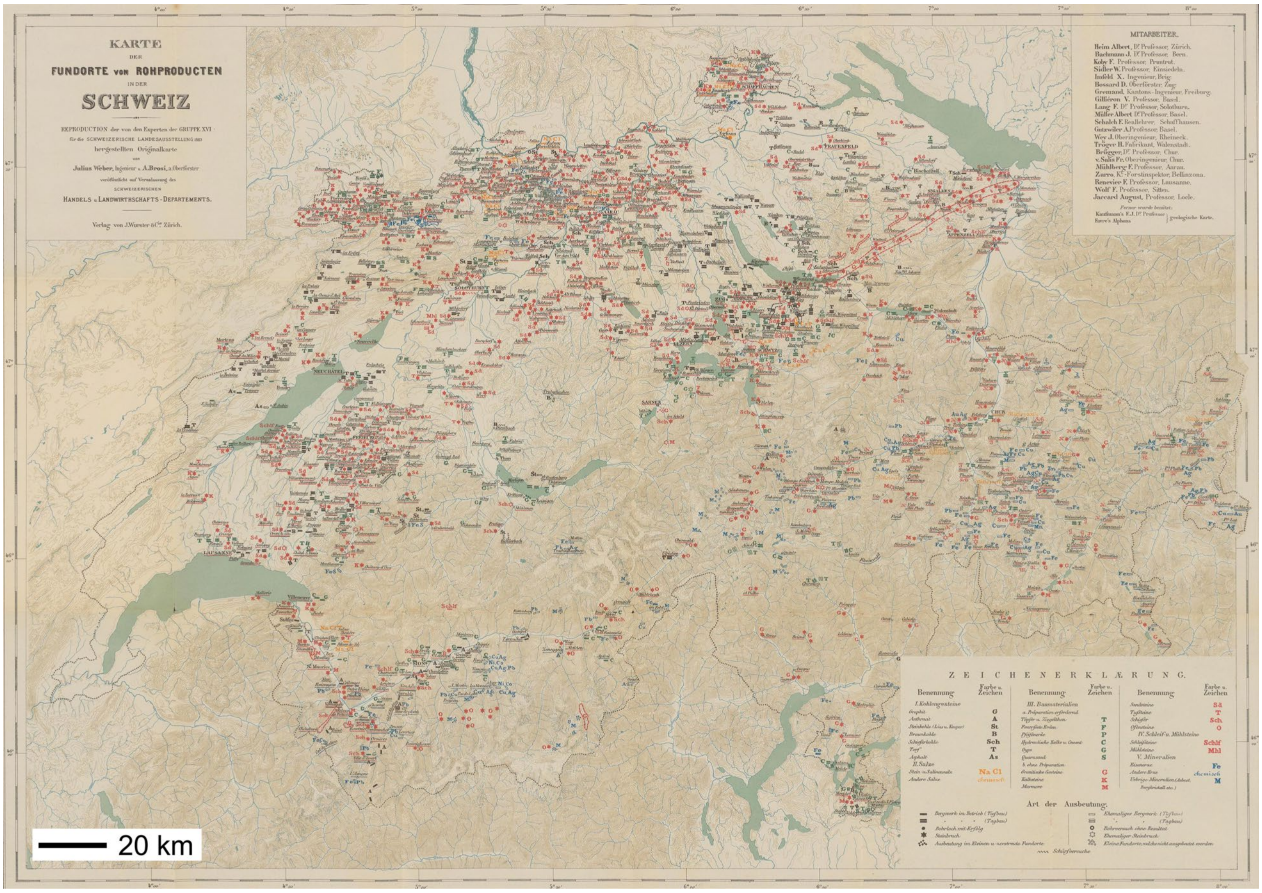

Fig. 4 Georesources map of Switzerland (1:500′000) by Weber and Brosi (1883). This map was presented at the first national exhibition 1883 in Zurich and represents the first compilation of this kind at the Switzerland scale. In order to get an overview on the areas that were explored the most, the map is shown here in its full extent. Details are not readable at that map scale. A high resolution version of this map is available here: https://www.e-rara.ch/zuz/doi/10.3931/e-rara-31156. Explanation of the symbols' colours: *black*: coal, peat, asphalt; *yellow*: salt, *dark green*: construction stones raw materials (clays, gypsum, quartz sand, hydraulic limestone, refractory soil); *red*: natural stones (granite, limestone, marble, sandstone, tuff, schist, potstone); *blue*: minerals (iron ore, other ores and minerals)

In the second half of nineteenth century, the construction of a modern transport infrastructure (e.g., railroad lines, bridges, tunnels, military) of the young federal state led to an increasing demand for fundamental topographic and geological data (i.e., maps) at a national scale (e.g., Jung, 2020). To educate experts for this immense construction phase, the Swiss Federal Institute of Technology (ETH Zurich) was founded in 1855, at that time named *Polytechnikum*. Besides engineering know-how, also expertise on energy resources (hydrocarbons) and mineral resources (e.g., construction stones, gravel, cement raw materials, brickyard raw materials) was demanded. However, a national geological survey that would co-promote the georesources applied research at a national scale did not exist yet.

3 The search for coal in the mid-late nineteenth century and the formation of the Swiss Geotechnical Commission (SGTK)

3.1 Public–private coal prospection

In the mid-late nineteenth century, the most important mineral resource in Switzerland was coal. The coal demand increased at a European scale during and after the Franco-Prussian War (1870–1871). The detailed geological mapping of Switzerland by the SGK covered only one of the tasks typically carried out by national geological surveys, investigations on georesources were missing. Although several raw materials compilation and mapping programs were run by institutions such as the SNG, mandated by governmental organisations, initiatives were also taken by the private sector. In 1874, a consortium of Swiss industrialists founded the Swiss Coal Drilling Society (Schweizerische Steinkohlenbohrgesellschaft, Letsch,

SGTK key monograph volumes in *Beiträge zur Geologie der Schweiz - Geotechnische Serie*

Authors	Main topic	Initiated and co-organised by	Pages	National Map
Letsch (1899)	Coal (Molasse)	Swiss Coal Drilling Society & Swiss Coal Commission & Bureau for Mining (1917-1923)	253	
Kissling (1903)	Coal (Molasse)		76	
Wehrli (1919)	Coal (Alps)		132	
Heim & Hartmann (1919)	Oil (Molasse)		95	
Frey (1922)	Aspalt		36	
Baumberger et al. (1923a)	Coal (Quaternary)		526	
Letsch & Ritter (1925)	Coal (Molasse)		104	
Wehrli (1925)	Coal (Alps)		168	
Früh & Schröter (1904)	Peat	Swiss Peat Bog Commission	751	1:530’000
Letsch et al. (1907)	Clays	Empa & Schweiz. Zieglerverein	680	1:530’000
Niggli et al. (1915)	Building Stones	Empa	423	1:500’000

Special volume “*Erdölgeologische Untersuchungen in der Schweiz*”

Authors	Main topic	Initiated and co-organised by	Pages
Althaus & Rickenbach (1947)	Oil (Molasse), Asphalt (Jura), Gas	Bureau for Mining (1941-1945) & PEK (1945-1949)	88
Erni & Kelterborn (1948)	Oil (Molasse)		51
Schuppli (1950, 1952)	Oil (Molasse)		41, 79

Special volume “*Die Eisen- und Manganerze der Schweiz*”

Authors	Main topic	Initiated and co-organised by	Pages
Baumberger et al. (1923b)	Fe, Mn ores (Jura, Alps)	Study Society for the Exploitation of Swiss ore deposits	283
Jeannet (1951), Frei (1952), Bodmer (1978)	Fe ores (Jura)		240,162 63
Déverin (1945), Hugi et al. (1948) Delaloye (1966), Tröhler (1966)	Fe ores (Alps)		115, 116 71, 137
Fehlmann (1932), Fehlmann & de Quervain (1952), Fehlmann & Rickenbach (1962)	Fe ores (Jura, Alps)		255, 31 121

Fig. 5 Overview of the most significant SGTK monographs that were published in the Geotechnical Series (*Beiträge zur Geologie der Schweiz—Geotechnische Serie).* The first box lists the 8 volumes on hydrocarbons that were initiated before or in the earliest years of SGTK. The three volumes below are also very early (1904–1915) works and of great volume. They all include a nation-wide occurrences map and extensive, systematic statistics of the various material tests on samples from all the documented occurrences. The second and third box list the monographs of the two special volumes documenting the then main SGTK research focus on oil (1940 to early 1950s) and on iron ores (ca. 1950–1960s). The SGTK monographs *Beiträge zur Geologie der Schweiz* can be downloaded here: https://shop.swisstopo.admin.ch/de/products/publications/geology/contributionsgeo/BGSD

1899, Figs. 2, 3). This organisation was mainly financing exploration drillings in the Canton of Aargau (Feer-Herzog, 1876). The first well at Weierfeld near Rheinfelden was, however, not successful. It reached the crystalline basement underlying the Mesozoic strata, instead of the aimed Permo-Carboniferous sediments. As a consequence, the society ran out of money. Subsequently, several other drilling attempts were undertaken by private initiatives, also without success, mostly because there was no sufficient funding for geological expertise (Schmidt et al., 1924). As a result, the SNG founded the Swiss Coal Commission as a new subcommission of the SGK in 1892 (Figs. 2, 3, Letsch, 1899). This subcommission established a comprehensive research program to study Switzerland’s hydrocarbon occurrences covering all geological domains of Switzerland (Fig. 1, Aeppli, 1915). This long-lasting research program was completed and made public by the later Swiss Geotechnical Commission in the form of eight monographs. It was supplemented by an investigation on Switzerland’s peat occurrences, initiated by the Swiss Peat Bog Commission which was an SNG commission from 1890 to 1904 (Früh & Schröter, 1904, Figs. 2, 3). This study resulted in an extensive monograph (Fig. 5) including a 1:530′000 occurrences map, which still represents one of the most comprehensive inventory of organic soils (e.g. Wüst-Galley et al., 2015).

3.2 The foundation of the SGTK

With the successful and nation-wide investigations on Swiss coal resources it became clear that research and documentation regarding other georesources needed to be institutionalised as well. In 1897, after consulting the head of SGK, professor A. Heim, and the director of Empa, L. Tetmajer, Fribourg state council (Ständerat) A. Bossy submitted a motion in the Council of States with the aim to "investigate and document the technically useable materials of Switzerland" (de Quervain, 1949; Letsch, 1899). As A. Bossy became national council (Nationalrat) in 1898, his motion was delayed and finally submitted to the National Council. In the meantime, professor L. Duparc needed additional funding for completing and extending his map on Swiss raw materials that he presented in the 1896 national exhibition. Together with professor C. Schmidt, his colleague from University of Basel, he applied for federal funding in 1898 (Grubenmann, 1915). Due to these two contemporaneous inquiries, the Swiss Federal Council approved the foundation of the Swiss Geotechnical Commission (*Schweizerische Geotechnische Kommission* SGTK) as a subcommission of SGK on 10th May 1899 (Figs. 2, 3).

The main mission of this new commission was to investigate all types of geological raw materials, document their occurrence in Switzerland and evaluate their technical properties for the industry. More precisely, the SGTK should undertake studies aiming at obtaining a better knowledge of the Swiss underground regarding the industrial exploitation of its rocks and minerals (SGTK, 1900). The name "geotechnical commission" given in 1899 seems rather misleading today. The name does not refer to geotechnical engineering, but to the objective of the commission, which was to investigate "technically useable materials". At the foundation of the SGTK, two main goals were defined: (1) the revision of the raw materials map by Weber and Brosi (1883) at 1:500′000 scale and a refinement of this map at the 1:250′000 or 1:200′000 scales, and (2) to establish a series of monographs covering the key georesources peat, coal, petroleum, asphalt, salt, gypsum, clay, cement raw materials, sand, (roof) slates, construction stones, oven stones, ores and minerals (for trade and for grindery). Such monographs were later published in the Geotechnical Series (*Geotechnische Serie*, Fig. 5), a new subseries within the existing *Beiträge zur Geologie der Schweiz* issued by the SNG.

3.3 First SGTK georesources compilations (hydrocarbons, clays, construction stones)

With the foundation of the SGTK, the Swiss Coal Commission became virtually meaningless and the SGTK took over the draft reports on the Swiss coal occurrences. The first report was published the same year (Letsch, 1899). Other reports followed between 1903 and 1925 (Baumberger, Gerber, et al., 1923; Frey, 1922; Heim & Hartmann, 1919; Kissling, 1903; Letsch & Ritter, 1925; Wehrli, 1919, 1925). These reports, together with the extensive compilation on Switzerland's peat occurrences (Früh & Schröter, 1904), all represent first national, systematic compilations of hydrocarbon occurrences in Switzerland (Fig. 5). They include detailed stratigraphic and lithological descriptions of the host rocks, volume estimations and petrography of the hydrocarbon units or reservoir rocks and detailed descriptions of the production sites (i.e. quarries, mines) including the exploration history, the production periods and the profitability. These monographs are based on extensive literature reviews, but also compile systematic laboratory analyses and (minor) geological field investigations. The Coal Commission's aim with these studies was mainly to document the state of knowledge on the occurrence of hydrocarbons. At the time of publication, these reports formed an up to date and very systematic overview of hydrocarbon occurrences at the Switzerland scale.

Another main research focus in SGTK's first years were clays. In 1894, L. Tetmajer and colleagues from Empa initiated a project targeting Switzerland's clay deposits. The interdisciplinary applied research project benefited from a 12 years lasting collaboration between Empa, the Swiss bricklayers association (*Schweizerischer Zieglerverein*) and SGTK. It resulted in an extensive monograph by Letsch et al. (1907, Fig. 5) comprising (1) a detailed documentation of more than 600 clay occurrences in Switzerland including a 1:530′000 map overview (Fig. 6), (2) an experimental evaluation of the petrographic and physical properties of clays from all quarry sites and (3) a statistical overview of the produced and traded (import, export) brickstones.

A third focus early on were building stones. The future SGTK president P. Niggli headed a testing and compilation project that resulted in an immense monograph on a representative assembly of the building stones and roof slates in Switzerland (Fig. 5, Niggli et al., 1915). It included a 1:500′000 occurrences map (Fig. 7) and a corresponding rock collection that are still highly regarded today (e.g. Wichert, 2020).

3.4 The first national georesources map by SGTK

Still aiming at the initially planned update of the georesources map by Brosi & Weber (1883), Schmidt (1917) compiled an overview map, including all types of hydrocarbons, salt and metallic ores, including explanatory notes (Fig. 8). An extended French version of the explanatory notes was published three years later (Schmidt, 1920). This mapping and sampling program produced a large reference collection containing 3′683 minerals and rocks and 419 thin sections. This SGTK collection, today kept in the Natural History Museum Basel, illustrates the Swiss Federal efforts to investigate and document the domestic mining activities during the mid-late

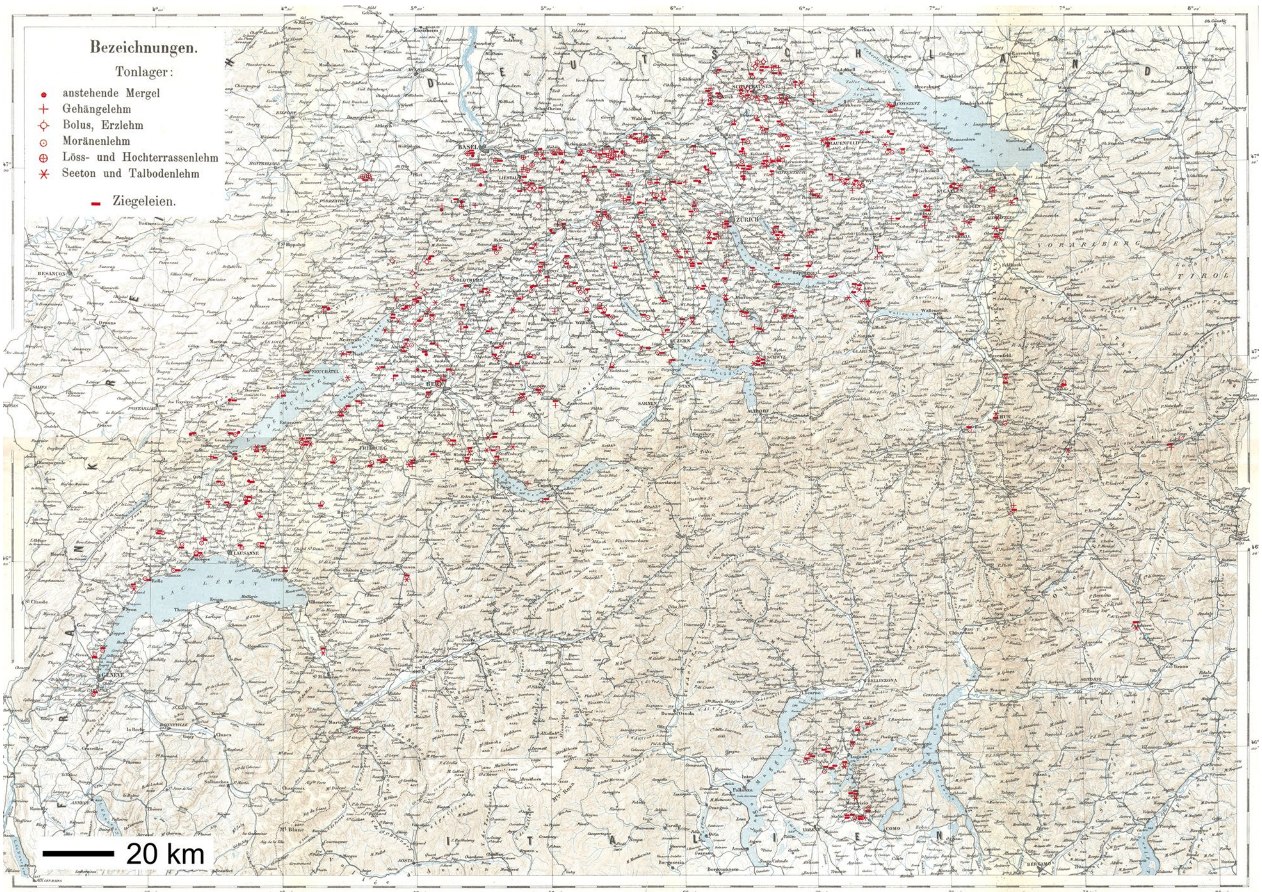

Fig. 6 Clay resources map (1:530′000) by Letsch et al. (1907). The map is shown in its full extent in order to get an overview of the areas that were explored the most. Details are not readable at that map scale. See the full resolution of this map in Additional file 1. The star-, cross- and circle-like red symbols represent occurrences of different types of clays, marls or brickearth. The fat dashes mark brick factories. Note that most of the occurrences, i.e. mining sites at the beginning of twentieth century were located in the Molasse Basin and in the Jura fold-and-thrust belt

nineteenth and earliest twentieth century (NHMB 2016, Puschnig & Schneider, 2006).

3.5 Relevance of SGTK monographs

The monographs and maps of the SGTK projects reports from the first 25 years of SGTK applied research represent the first occurrences-focused data bases at a national scale (Fig. 5). The availability of these monographs, including key raw material properties and occurrences maps, did not lead directly to new and significant prospection or exploration activity. The documented occurrences were rather small and the political situation became more unstable during and after World War I.

Whereas the SGTK team produced four nation-wide raw material maps on single or only a selection of georesources in the early years (Früh & Schröter, 1904; Letsch et al., 1907; Niggli et al., 1915; Schmidt, 1917), the long-term goal of an all-including georesources map followed in the 1930s. Niggli and de Quervain (1934, 1935, 1936, 1938) published the first comprehensive raw materials map, including all then active production sites of mineral resources at the 1:200′000 scale (*Geotechnische Karte der Schweiz*).

4 Energy resources vs. metallic ores—shifting focus in the mid-twentieth century

4.1 Coal exploration during World War I (the Swiss Federal Bureau for Mining—part 1)

After the publication of the first Geotechnical Series monographs and in recognition of its importance, the SNG transformed the SGTK into an independent commission in 1909 (Grubenmann, 1915, Figs. 2, 3). The Swiss Coal Commission and the Swiss Coal Drilling Society were dissolved after World War I in 1919 and 1923, respectively (Fig. 2). From 1909 onward, Switzerland's geological surveying was conducted by the Swiss Geological and Swiss Geotechnical Commissions which focused

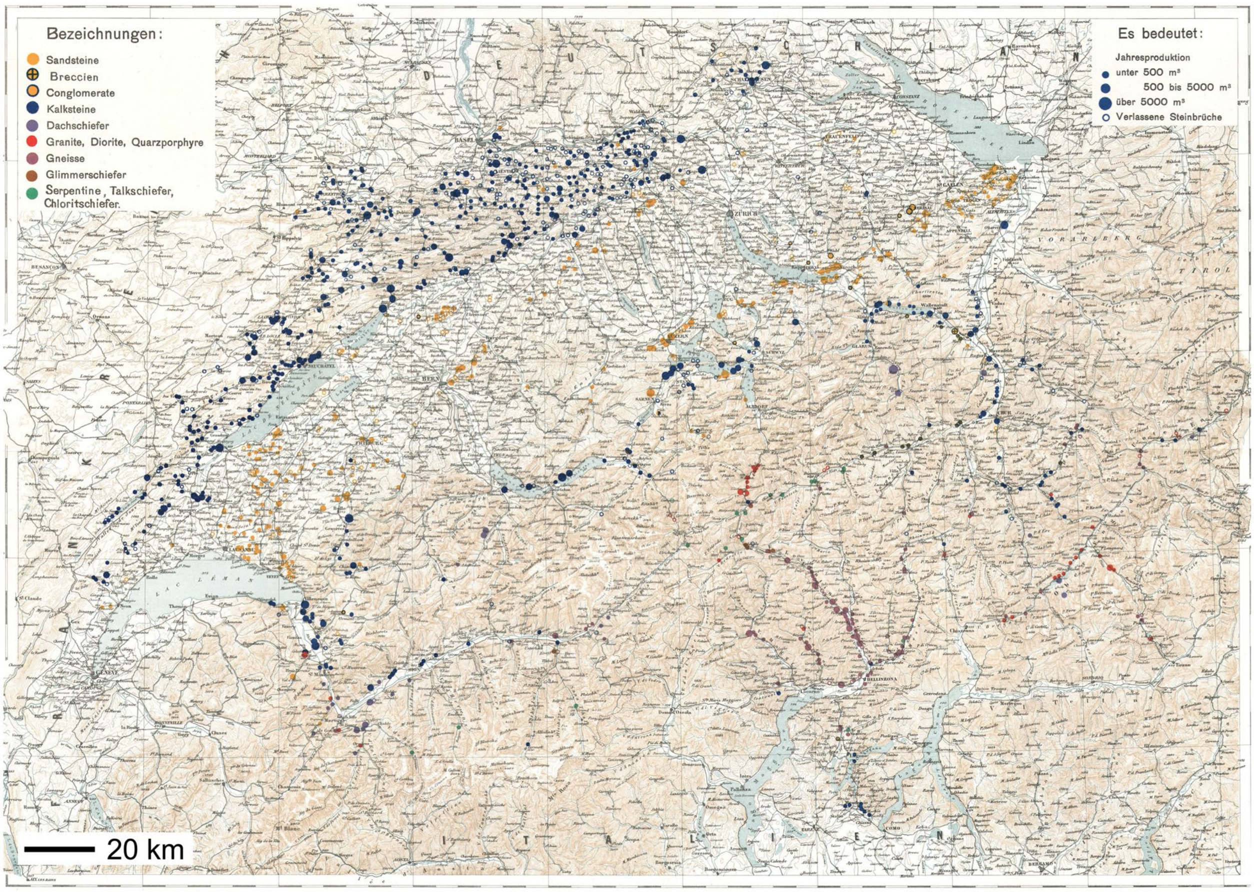

Fig. 7 Building stones quarries map (1:500′000) by Niggli et al. (1915). The map is shown in its full extent in order to get an overview of the areas that were explored the most. Details are not readable at that map scale. See the full resolution of this map in Additional file 2. Explanation of circle symbols colours: *blue*: limestones, *yellow*: sandstones, *blue-grey*: roof slates, *red*: granites, *purple*: gneisses, *brown*: mica schists, *green*: serpentinites & talcschists. The size of the circles represents the amount of extracted material. Empty circles highlight abandoned quarries. Note that limestones occur and were mined along both the Jura and the Helvetic Nappes of the Alps; sandstone quarries were located exclusively in the Molasse Basin

on geological mapping and assessment of the natural resources, respectively.

Around the turn of the century, the national coal production almost broke off and hydropower gained importance (Baumberger et al., 1923a; Wehrli, 1925). However, coal remained the main energy resource until World War II and needed to be imported from neighbouring European countries. During World War I, coal and metallic ore resources were highly demanded all over Europe and in Switzerland only mined in Delémont (iron ores, location no. 3 in Fig. 10) and in Val de Travers (bitumen, location no. 45 in Fig. 10, Frey, 1922, Fehlmann, 1943). As a consequence, in 1917, the Swiss Federation established the Federal Bureau for Mining (*Bureau für Bergbau*) as a section of the Department of Industrial Warfare in the Federal Department of Economic Affairs (Fehlmann, 1919, Figs. 2, 3). This office was supported by SGTK and launched several projects to explore critical energy and metal resources in Switzerland. Due to the increasing shortage during the war, Swiss companies started mining coal beds that were of comparatively poor quality (of less than 20 cm thickness) which would not have been extracted in other European countries. Although mining at small scales became temporarily more important during that time and was subsidised by the federation, coal production in Switzerland reached only about 116′000 t in 1918 (Fig. 9). Only a fraction of this coal could be used because of the poor quality (Fehlmann, 1919). In the same year, coal import into Switzerland reached about 2.1 mio. t (Schmidt et al., 1924).

Despite intensified exploration during these few years with extra resources for the Bureau for Mining, no additional deposits were found and thus no significant mining industry developed. The bureau, however, compiled the know-how of the studied mineral resources. The final report by Fehlmann (1919) documented the state

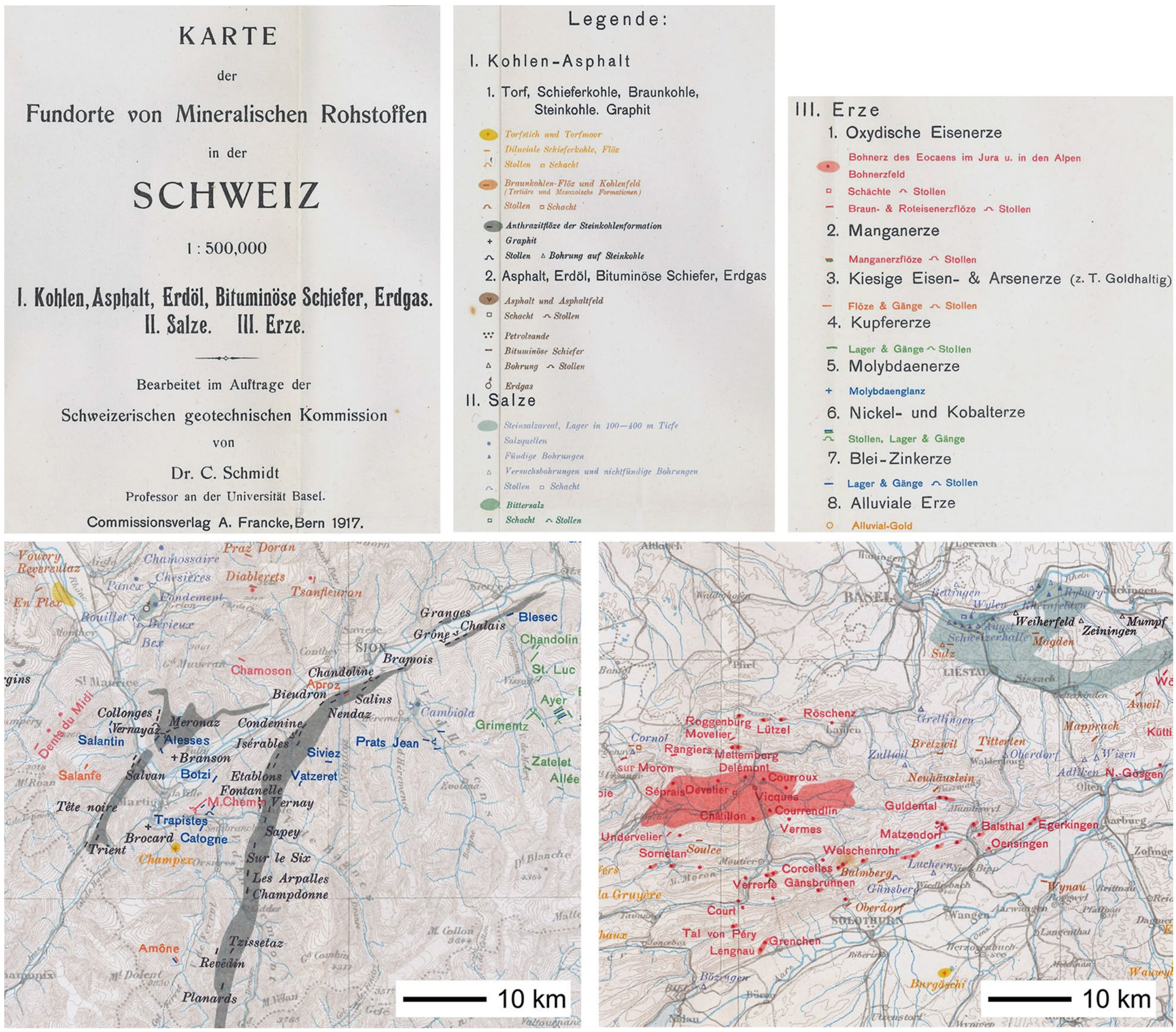

Fig. 8 Extracts of the georesources map (1:500′000) by Schmidt (1917). *top*: extracts from the map header and the legend. The displayed raw materials are sorted in groups: (I.1) peat, coal, graphite, (I.2) asphalt, oil, bituminous schists, gas, (II) salt, (III) ores (Fe, Mn, Cu, Mo, Ni, Co, Pb, Zn, Au). *bottom left:* extract of the lower Valais area (SW Switzerland) illustrating the anthracite/hard occurrences in the Permian and Carboniferous units in the Zone Houillère and the Aiguilles Rouges Massif (dark grey polygons). *bottom right*: extract of the area between Basel and Solothurn (central northern Switzerland). The red polygon marks an area with high concentration of Eocene pisolithic iron ore deposits ("Bohnerz") in the Jura fold-and-thrust belt south of Delémont. The pale grey polygon illustrates the belt of halite deposits occurring in the Triassic units southwest of Basel at ca. 100–400 m depth. See the full extent and resolution of this map in Additional file 3. For location of the two map extracts see Fig. 1

of mining activities at the time, including occurrences of hard coal (anthracite), brown coal (lignite), slate coal, talc and asbestos and different ores like pyrite, copper, lead, zinc, nickel, cobalt and molybdenum. The ore deposits generally showed very low metal contents and very heterogeneous ore distributions within the host rocks. Furthermore, the report demonstrated that the volume and grade of the deposits were too low, so that further processing and smelting would have been required. The coal deposits were too rare, too thin and of moderate quality. Finally, this report confirmed what was known before: coal and ore mining, even with the increased financial support during WW I, is practically non-ecomomic in Switzerland (Fehlmann, 1919).

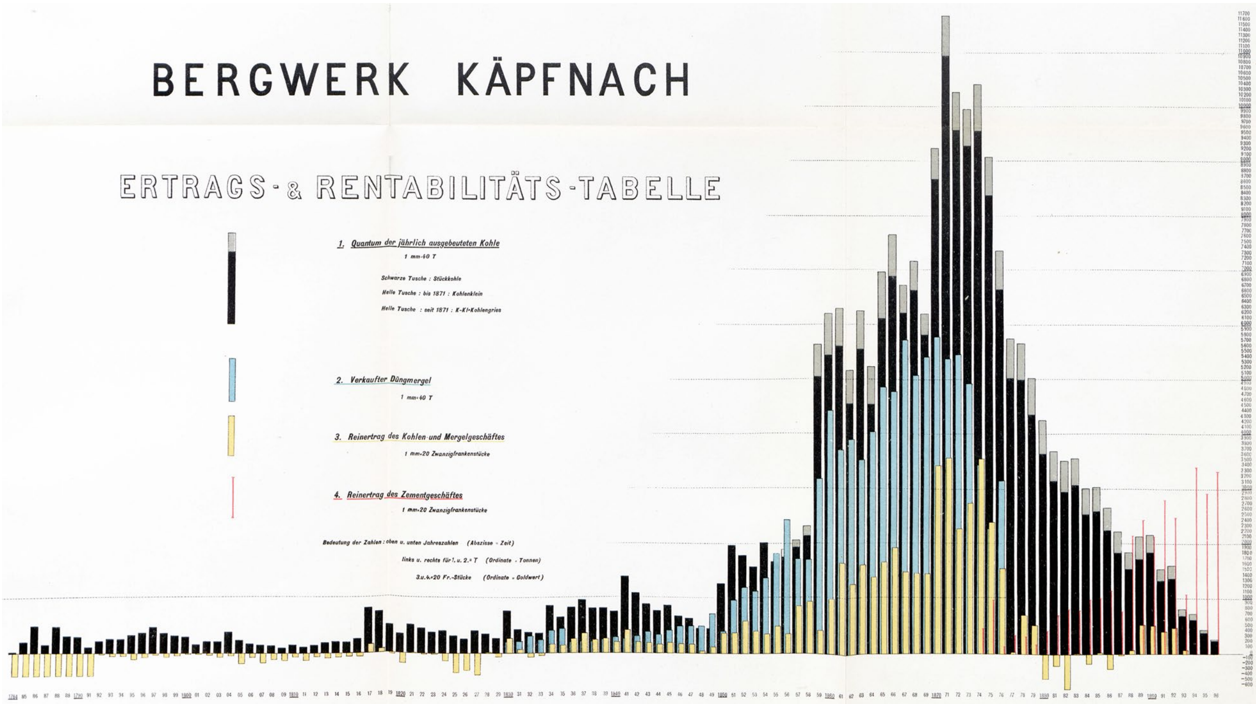

Fig. 9 Outputs and revenues of coal production at the Käpfnach mine during 113 years (reproduced from Letsch, 1899). Vertical axis: tonnages and revenues from 1784–1896. The black bars mark the tonnages of the extracted coal with a maximum of 11′693 t in 1871 (highest bar). *Black*: produced coal per year (t), *blue*: produced fertilising marl (t), *yellow*: revenues from coal and marl sales (CHF). This coal mine was located near Horgen, situated in the Upper Freshwater Molasse close Lake Zurich, and was first documented in 1548. See Fig. 1 for location of the mine

4.2 Shift to research on metallic ores after World War I (the Study Society for the Exploitation of Swiss ore deposits)

The Bureau for Mining focused on coal occurrences and had no capacity to investigate other critical mineral resources such as salt, asphalt (bitumen), iron or manganese. When the bureau was closed after World War I, its representatives made clear that the systematic investigation of the Swiss ore deposits needed a new institution (Fehlmann, 1943). In consequence, the Swiss Federal Department of Economic Affairs together with several companies of the Swiss iron and cement industry founded the Study Society for the Exploitation of Swiss ore deposits (*Studiengesellschaft für die Nutzbarmachung der schweizerischen Erzlagerstätten*, in the following referred to as Study Society) in 1918 (Baumberger et al., 1923b; Fehlmann, 1943, Figs. 2, 3). It was led by H. Fehlmann (until 1957), the former head of the Bureau for Mining and SGTK member since 1919, and, together with SGTK, took over all the documentations and working programs from the Bureau for Mining (Niggli, 1966).

Switzerland's metal resources were still poorly documented (Fehlmann, 1919). Therefore, the Study Society and SGTK extended the investigations to iron ore deposits and to deposits of other metals that were required for producing high quality steel (Fehlmann & Rickenbach, 1962; Fehlmann, 1943). It was originally assumed that there would be other Swiss companies willing to participate in these exploration studies of domestic mineral raw materials. Even though this expectation did not fulfill, this work resulted in a series of 11 extensive publications on iron and manganese ores (Fig. 5, Baumberger et al., 1923b; Bodmer, 1978; Delaloye, 1966; Déverin, 1945; Fehlmann, 1932; Fehlmann & de Quervain, 1952; Fehlmann & Rickenbach, 1962; Frei, 1952; Hugi et al., 1948; Jeannet, 1951; Tröhler, 1966).

These reports represent a systematic overview of the metallic ore occurrences in Switzerland known at that time (Fig. 10), summarise the geological setting of the ore-bearing lithological units in great detail and give an overview of the exploration and production back then and earlier on. The stratigraphic units of interest were the Middle Jurassic iron oolites (e.g. Herznach member in the Jura [location no. 1 in Fig. 10], Erzegg Formation in the Helvetic Nappes [no. 6]), the Eocene ferruginous pisoliths (Bohnerz formation in the Jura [no. 2 & 3]) and magnetite skarns (Mont Blanc Massif units in the Mont Chemin area [no. 10]). As neither the Study Society nor

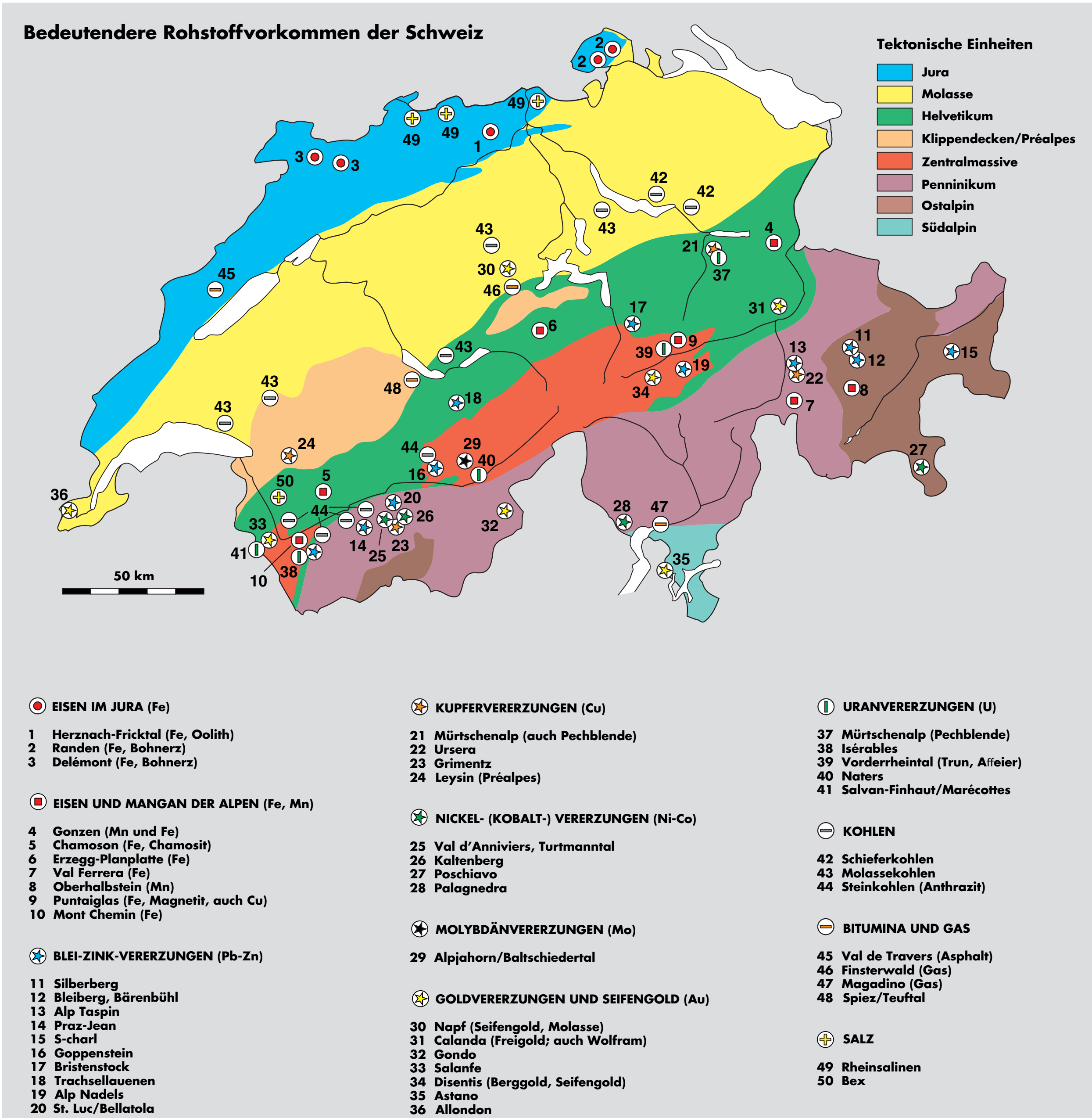

Fig. 10 Occurrences of important mineral resources (hydrocarbons, ores, salt) in Switzerland in the twentieth century (reproduced from Kündig et al., 1997). *Red circle*: Fe ores in the Jura fold-and-thrust beld, *red square*: Fe and Mn ores in the Alps, *blue star*: Pb–Zn ores (the missing number to the blue star in the very southwest labels the occurrences at Mont Chemin), *orange star*: Cu ores, *green star*: Ni-Co ores, *black star*: Mo ores, *yellow star*: Au ores and placer, *blue-green vertical dash*: U ores, *grey dashes*: coal, *orange dash*: asphalt and gas, *yellow cross*: salt

SGTK had sufficient funding, no new, extensive mineral exploration could be carried out and no new discoveries were made. As a comparison, the discovery of the largest tungsten deposit in Europe in 1967, the scheelite deposit in the Felbertal (Austrian Alps), was made possible by a comprehensive mineral exploration program in Austria (e.g. Raith & Schmidt, 2010; Thalhammer et al., 1989). The program was done in an area that was mapped before but not thoroughly studied with a focus on mineral resources. This example shows that also in the Swiss Alps such mineral occurrences cannot be completely ruled out as long as a systematic exploration is missing.

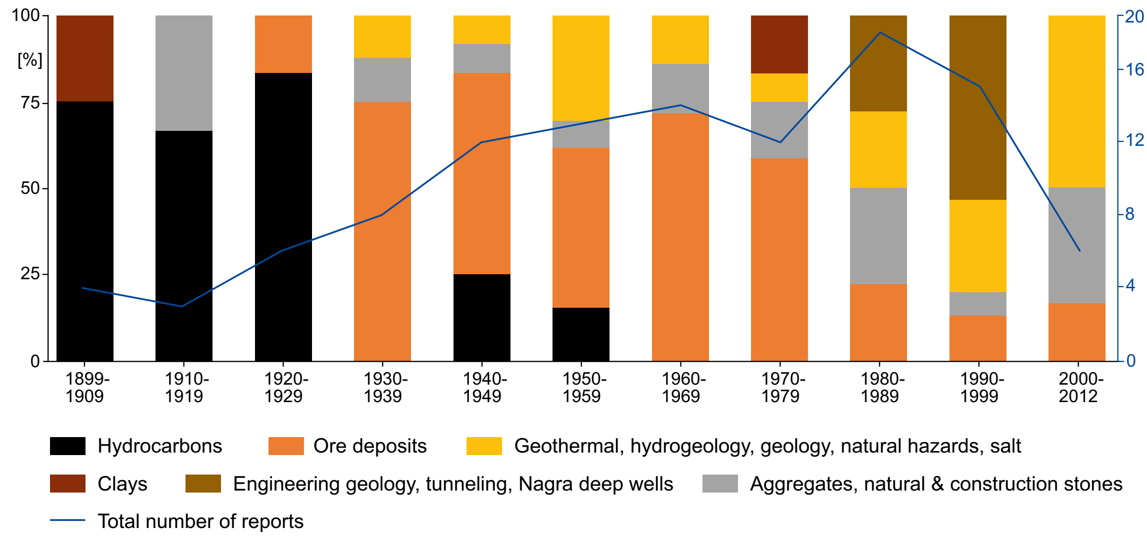

Fig. 11 Main SGTK research focus areas derived from the topics of the Geotechnical Series monographs from 1899 to 2012. Vertical axis: % of the total amount of reports. Note (1) the clear focus on hydrocarbons in the first three decades, (2) the shift in the 1930s towards ore deposits, (3) the hydrocarbons interlude in the 1940s and 50s, (4) the increasing diversification from the 1970s onwards and (5) the fast decline of number of reports since the 1980s

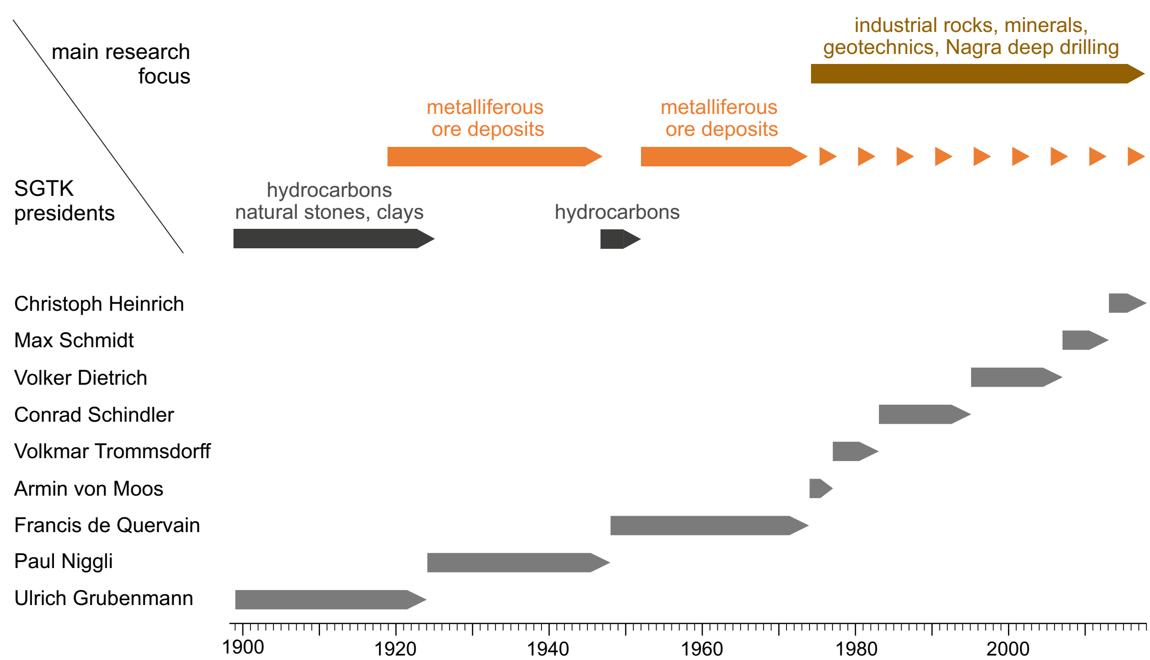

Fig. 12 *Top*: The SGTK research focus topics through time, compiled and simplified from the Geotechnical Series topics illustrated in Fig. 11. *Bottom*: Chronological overview of the SGTK presidents. All presidents were professors at Earth Sciences institutes at ETH Zurich except A. Von Moos. Their presidential terms were: U. Grubenmann 1899–1924, P. Niggli 1924–1948, F. de Quervain, 1949–1974, A. von Moos 1975–1977, V. Trommsdorff 1978–1983, C. Schindler 1984–1995, V. Dietrich 1996–2007, M. Schmidt 2008–2013, C. Heinrich 2014–2018. Note the apparent coincidence of the three first presidency terms with the two main research focus topics (1. hydrocarbons, natural stones, clays, 2. metalliferous ores) during the first ca. 75 years

After World War I, the focus generally shifted away from hydrocarbons, building stones and clays towards metallic ores (Figs. 11, 12). Although this shift coincided with the handover of the SGTK presidency from U. Grubenmann to P. Niggli in 1924, it is not clear whether the change in leadership really had an impact on the focus of research (Fig. 12). Both directors were mineralogists and professors at ETH Zurich. After H. Fehlmann's resignment from the management in 1957, the Study Society widened its focus to cover more non-metallic mineral resources and established a more formal working partnership (syndicate) with the SGTK (Fehlmann & Rickenbach, 1962). However, during the 1990s, the Study Society started to lose its relevance for georesources research. No large new investigation programs were launched and the organisation changed its name twice (1998, 2011). Today, it is called NEROS (Mineral Resources Network Switzerland, *Netzwerk mineralische Rohstoffe Schweiz*) and it is active mainly as networking organisation aiming to raise the awareness for the use and securing of Swiss georesources at a national level.

4.3 Hydrocarbons interlude during the Great Depression (the Petroleum Expert Commission)

The phase during which the SGTK mainly focused on metallic ore deposits was temporarily interrupted by the renewed demand for energy resources (i.e. hydrocarbons) during World War II (Fig. 12). Already during the Great Depression, in 1935, the Federal Central Office for Job Creation of the Federal Department of Economic Affairs (*Eidgenössische Zentralstelle für Arbeitsbeschaffung des Eidgenössischen Volkswirtschaftsdepartementes*) launched a consulting commission called Geotechnical Information Centre (*Geotechnische Beratungsstelle*) with the mission to consult the federal offices regarding georesources. The Centre set up a new, temporary SGTK subcommission, the Petroleum Expert Commission (*Petroleum-Expertenkommission* PEK, Figs. 2, 3) that hired renowned but then unemployed Swiss geologists like for example Arnold Heim. Main study focus was the northwestern Swiss Molasse Basin and the adjacent southern parts of the Jura fold-and-thrust belt where oil and gas indications were already known and partially studied. Most previous hydrocarbon wells since World War I for example at Les Granges (GE, drilled 1888–1889), La Plaine (GE, 1889), Chavornay (VD, 1912), Arnex (VD, 1929) and Tuggen (SZ, 1925–1928) were not successful because they were geologically unfavourably placed (Althaus & Rickenbach, 1947). Other wells like Cuarny (VD, 1936–1940) or Servion (VD, 1938–1939) were better placed but technically poorly executed (Fig. 13). The PEK concluded that all these wells did not contribute enough to the hydrocarbon potential in Switzerland. Furthermore, the commission considered it unlikely to find significant amounts of oil in the Swiss Molasse Basin (Althaus & Rickenbach, 1947). The experts were a bit more optimistic regarding potential gas resources (Niggli, 1939). The PEK was dissolved in 1939.

With these federally sponsored hydrocarbon investigations, hydrocarbon traps in the Cenozoic Molasse units and in the Subjurassic Zone could be identified. However, there was no consensus regarding the profitability of potential wells (Niggli, 1939). The results were compiled and published by the SGTK just after World War II (see below).

4.4 Continued hydrocarbon prospection during World War II (the Swiss Federal Bureau for Mining and the Petroleum Expert Commission—part 2)

As Switzerland faced a shortage of energy resources during World War II, a Federal Bureau for Mining was established again by the Swiss Federation in 1941 (Niggli, 1966, Fig. 2). The intention was to come up with suggestions for new drilling sites based on a re-evaluation of existing but also of new structural and stratigraphic investigations mainly in the Cenozoic Molasse units. In a further step, the bureau wanted to initiate a national drilling program, raise funds for several drilling rigs and tried to install a society for the study of Swiss oil resources, following the example of the existing Study Society for the Exploitation of Swiss ore deposits. The fundraising was, however, not successful and thus no new wells could be drilled. After the war and the renewed dissolution of the Bureau for Mining in 1945 (de Quervain 1949), SGTK compiled all these petroleum studies and published them in a special volume (Althaus & Rickenbach, 1947; Erni & Kelterborn, 1948; Schuppli, 1950, 1952, Fig. 5). Scientific support came from the PEK, that re-constituted again from 1945 to 1949 (Fig. 2). The studies contain data from literature, from industry (drilling, trenching) projects and own field work by the PEK geologists (Fig. 14). They are basically compilations of existing knowledge of the stratigraphy and the tectonic setting with respect to potential hydrocarbon occurrences and oil and gas indications in the Swiss Molasse Basin. Indications were found mainly in the Oligocene Lower Freshwater Molasse located in the Subjurassic zone along the Jura fold-and-thrust belt and in the Subalpine Molasse with the traps being mainly anticlines or faults (Fig. 14).

4.5 Implications for private oil and gas exploration after World War II

Based on the PEK studies, the wells Altishofen and Chapelle were drilled in 1952–1953 and 1958, respectively (Fig. 13). Indications for hydrocarbons were found but the occurrences were estimated to be not

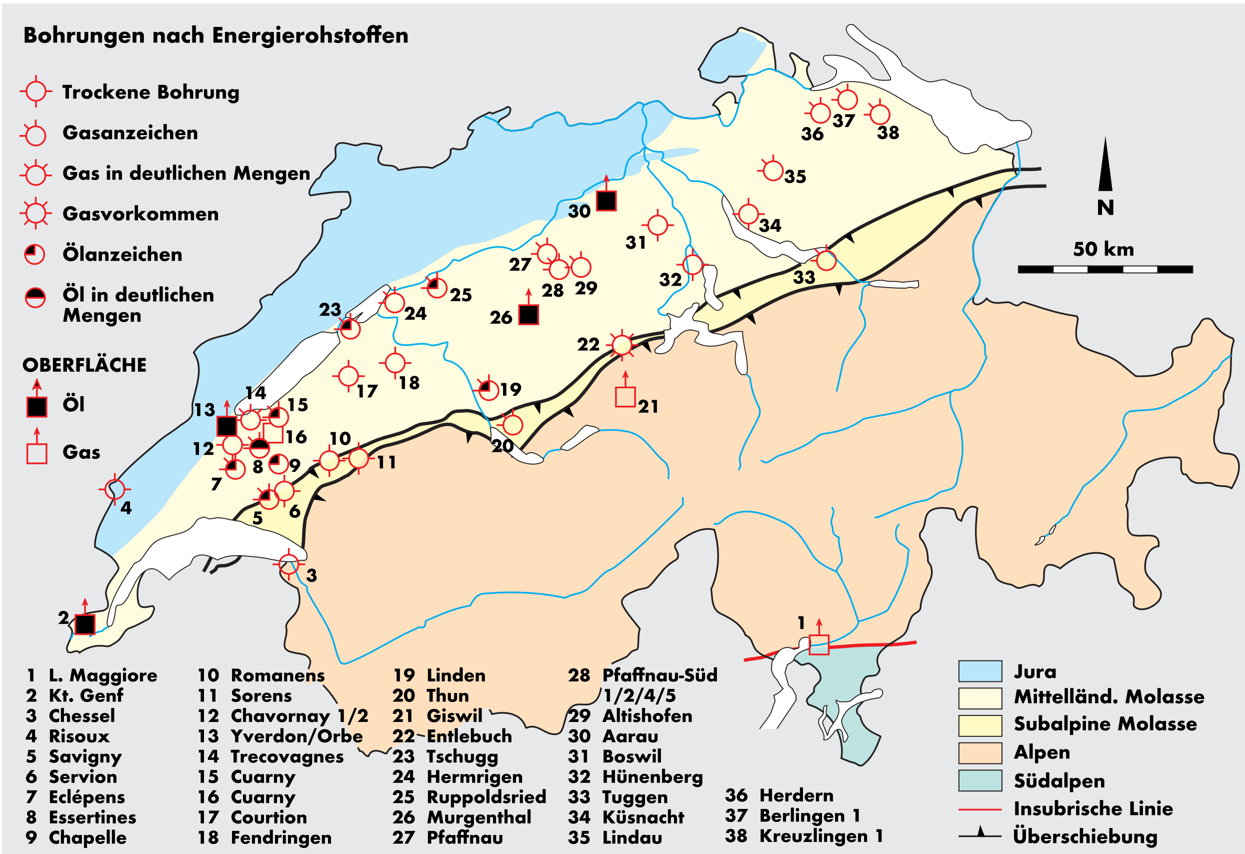

Fig. 13 Important hydrocarbon wells in Switzerland (reproduced from Kündig et al., 1997). The wells Chavornay-1 and -2 were drilled 1912, Tuggen 1925–1928, Servion 1938–1939, Cuarny 1936–1940, Altishofen 1952–1953, Chapelle 1958, Küsnacht 1960, Savigny 1960, Courtion 1960, Risoux 1960–1961, Sorrens 1961, Kreuzlingen-1 1962, Essertines 1963, Pfaffnau-1 1963, Lindau 1964, Pfaffnau-Süd 1964, Berlingen-1 1964, Boswil 1965, Hünenberg-1 1965, Pfaffnau-Süd-2 1965, Pfaffnau-Süd-4 1965, Pfaffnau-Süd-5 1966, Linden 1973, Tschugg 1976, Romanens 1977, Ruppoldsried 1977, Treycovagnes 1978, Entlebuch 1980, Eclépens 1981, Fendringen 1982, Herdern 1982, Hermrigen 1982, Chessel-1001 1987, Thun 1989 (Lahusen & Wyss, 1995). The point symbols, labelled in German, mean, from top to bottom: 1. dry well, 2. gas indication, 3. gas in significant quantities, 4. gas occurrence, 5. oil indication, 6. oil in significant quantities, 7. oil occurrences at the surface, 8. gas occurrence at the surface

economically producible (Lahusen & Wyss, 1995). The application of the reflection seismic as new exploration tool since the mid-1950s led to more reliable predictions and thus to a significant increase of wells drilled during the 1960s (Fig. 13).

In 1956, the investment company Swisspetrol Holding AG started coordinating a new phase of hydrocarbon exploration in the Molasse Basin focusing mainly on the Mesozoic and Permo-Carboniferous units (Lahusen & Wyss, 1995; Lahusen, 1992). Despite the above mentioned comprehensive data basis, including extensive reports on geology and (potential) hydrocarbon occurrences, the discoveries remained rather little. Until 1993, no commercially exploitable oil or gas occurrences were found in Switzerland except the natural gas trap in karstic Malm limestones at ca. 4.3 km depth in the Finsterwald well (Entlebuch, LU; Lahusen & Wyss, 1995; Leu, 2012). To date, neither oil nor gas has been exploited in Switzerland in larger commercial amounts.

5 SGTK organisation

5.1 SGTK presidents and thematic focus

Like other SNG commissions, SGTK was a group of experts led by a president. The number of experts increased over the years from 5 to 18, probably because of the diversification of research topics and the related specialisation of geoscientists. The presidents have almost exclusively been professors in the Earth Sciences institutes of ETH Zurich, with partly important political positions (e.g. SGTK presidents U. Grubenmann and P. Niggli were at the same time also rector of ETH Zurich, de Quervain, 1953; Wildi, 1924). The first

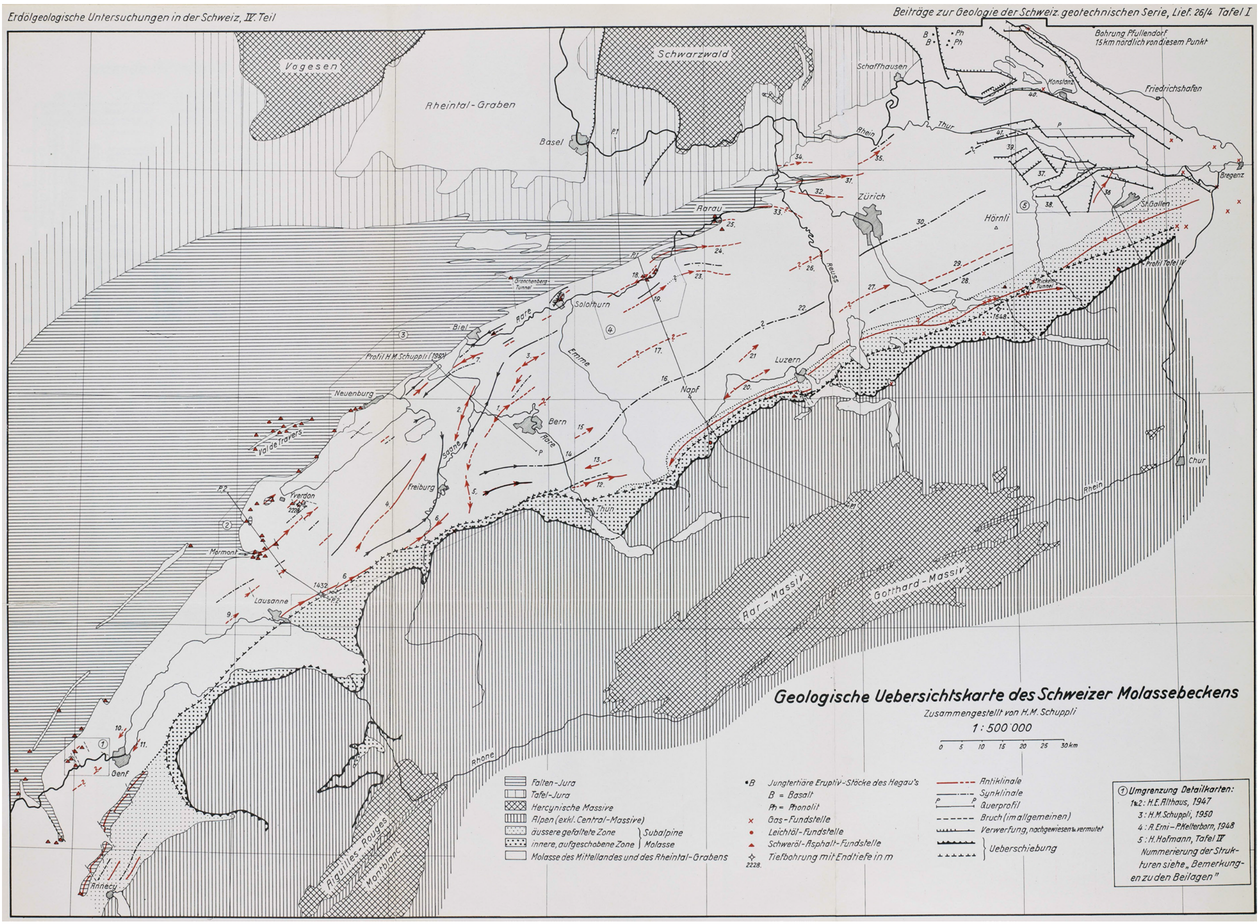

Fig. 14 Overview map of the Swiss Molasse Basin with its main structural features (reproduced from Schuppli, 1952). *Red line*: anticline, *dark blue line*: syncline, *black line*: fault, *red cross*: gas seep, *red circle*: light oil occurrence, *red triangle*: heavy oil or asphalt occurrence. Note the relatively high concentration of oil and asphalt findings along the southern edge of the Jura fold-and-thrust belt in western Switzerland, and the gas shows in the Subalpine Molasse along anticlines and fault traps at the southeastern end of Lake Zurich

three presidents, U. Grubenmann, P. Niggli and F. de Quervain, had very long terms and had a clear thematic focus (Fig. 12). Due to the very limited funding available (Fig. 15), the commission could only focus on a few topics at the same time. This resulted in the previously described landmark and very extensive monographs on coal, peat, clay and natural stones (e.g. Früh & Schröter, 1904; Letsch, 1899; Letsch et al., 1907; Niggli et al., 1915, Fig. 5), the installation of a Geotechnical Test Centre (*Geotechnische Prüfstelle*) in 1927 at the ETH Institute of Mineralogy and Petrography in collaboration with Empa (e.g. Niggli et al., 1930; Gschwind & Niggli, 1931), extensive studies on construction stones (e.g. de Quervain & Gschwind, 1949; de Quervain & Jenny, 1969; de Quervain, 1967; de Quervain et al., 1934; von Moos & de Quervain, 1948) and the update of the mineral resources map of Switzerland (Kündig & de Quervain, 1941, 1953). From 1975 onward, the presidents all had significantly shorter terms than the three first presidents (Fig. 12). At that time, SGTK started to increase collaborations with different geoscientific institutions and diversified its fields of research towards topics like environmental geology, hydrogeology, geochemistry and geotechnical engineering (e.g. de Quervain, 1949, 1974; Kündig et al., 1997). The Geotechnical Series subjects in Fig. 11 also highlight that the focus on metalliferous ore deposits came to an end after 1980.

5.2 SGTK office and funding

In the very early days, SGTK was a mere commission without an own office. In 1927, with the foundation of the Geotechnical Test Centre as joint institution of ETH Zurich and Empa, SGTK could recruit its first employees (de Quervain, 1949; Epprecht, 1988). Since 1927, ETH Zurich hosted the SGTK office as part of one of the Earth Sciences institutes. However, formally, SGTK remained

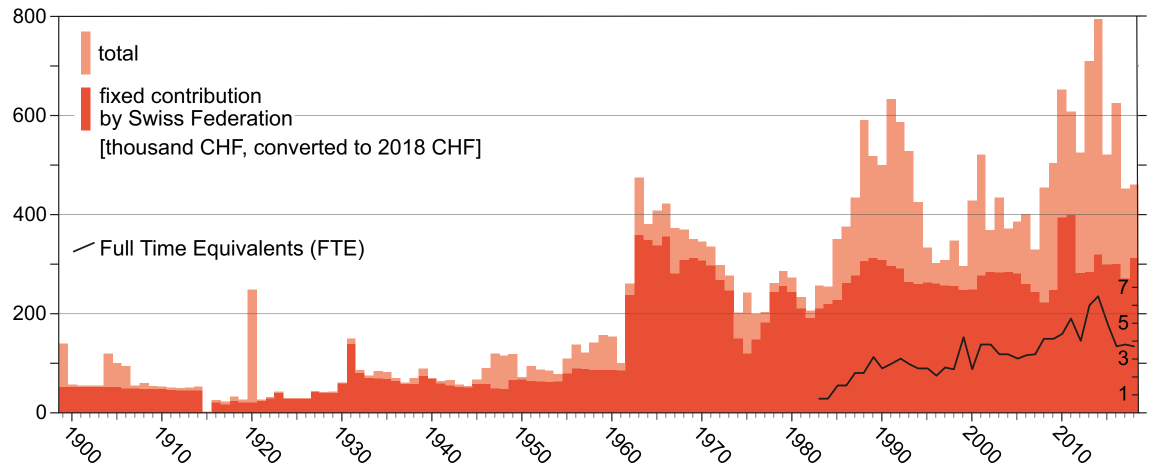

Fig. 15 Annual SGTK funding, split into the fix annual contribution from the Federation (dark red) and project-based contributions from various sponsors. Values are adjusted for inflation according to the Swiss Consumer Price Index by the Federal Statistical Office (BFS). Data between 1899 and 1974 are from SNG annual reports (SNG 1900–1974), data between 1975 and 2018 are from unpublished SGTK annual reports. The fixed contribution contains funding from SNG/SCNAT (funding since 1899), from different federal offices (since 1970) and from ETH Zurich (since 2002). The SNG/SCNAT share was 100% from 1899 to 1969 and declined to 4–10% after 1970. The share of the federal offices ranged between 75 and 97% of the total fixed contribution. Since the early 1960s, the fixed contribution by the federation (incl. SCNAT & ETH Zurich) was in the order of 220 to 350 kCHF. The non-fixed contribution during that period ranged between ca. 25 and 400 kCHF with an average of about 95 kCHF in the 1960–1990s and ca. 205 kCHF after 1999. A substantial part (up to about half) of the non-fixed contribution came also from the federation, mainly for the production of the different sheets of the Hydrogeological Maps (*Hydrogeologische Karte der Schweiz 1:100ʹ000*). The rest of the funding was raised through applied research projects for industry. Full time equivalents (FTE) are only given for the time after 1983, as SGTK was only able to finance own staff since then

an SNG commission, and from an administrative point of view, part of the SNG (later SCNAT).

Projects were designed by the professors, who were experts in the commission, and carried out by the staff of their institutes. During the 1940s, SGTK began to hire external, project-based staff at significantly lower salaries than what was common in industry at that time (e.g. 15 CHF for a field day in 1900, and 18 CHF per day in 1948, non-indexed values, de Quervain, 1949). SGTK researchers had access to the ETH infrastructure, in particular to the labs of the Institute of Mineralogy and Petrography and its successor institutes. In return, the Earth Sciences institutes benefited from the SGTK rock collections, its comprehensive library and since the late 1980s, from increasing contributions by SGTK staff to the Department of Earth Sciences' teaching program.

In 1989, after decades having been organised as a very small team with mainly temporary staff, SGTK, at that time under the presidency of C. Schindler, installed a managing director, R. Kündig, to lead the SGTK office at ETH Zurich. R. Kündig headed the SGTK office for 28 years, until 2016, and thus played a decisive role in shaping the development of the commission. One of his key achievements was pushing forward the digitalisation of resource extraction sites point data and of raw materials maps.

The source and amount of funding of the SGTK varied significantly over time (Fig. 15). During the first 60 years it consisted basically of a rather small federal contribution through SNG. In 1963, it significantly increased (from ca. 20 to 100 kCHF) because then, a fixed federal annual contribution was established mainly by annual contracts with varying federal offices. This increase was the result of a memorandum, compiled by SGTK together with SGK, that was handed in to the Federal Department of the Interior. The memorandum sketched the challenge of the two geo-commissions' working situations and successfully asked for more financial support (de Quervain, 1974). From 1984 onwards, SGTK president C. Schindler, an engineering geologist, successfully acquired additional funds from industry and different federal and cantonal offices, expanding the total budget by 100–500 kCHF. The annual contribution from the Swiss Geological Survey (swisstopo) and its corresponding predecessor federal units varied between about 200 and 250 kCHF since the late 1980s.

5.3 Publications, collections and digital archives

The results of the SGTK research were published in series, maps and monographs. *Beiträge zur Geologie der Schweiz—Geotechnische Serie* is the most important SGTK monograph series comprising 111 volumes

SGTK Monograph Series *Beiträge zur Geologie der Schweiz*	Years	Number
Geotechnische Serie	1899-2012	111
Geotechnische Serie, Kleinere Mitteilungen	1931-2000	96
Hydrologische Serie	1934-1989	34
Geophysikalische Serie	1957-1973	15

SGTK Maps and Explanatory Notes	Autors	Years	Scale	Sheets
Karte der Mineralische Rohstoffe der Schweiz	Schmidt	1917	1:500'000	1
Erläuterungen	Schmidt	1917		
Texte explicatif	Schmidt	1920		
Geotechnische Karte der Schweiz	Niggli & de Quervain	1934-1938	1:200'000	4
Fundstellen mineralischer Rohstoffe in der Schweiz	Kündig & de Quervain	1941	1:600'000	1
Erläuterungen	Kündig & de Quervain	1941, 1953		
Geotechnische Karte der Schweiz	De Quervain et al. [1]	1963-1967	1:200'000	4
Hydrogeologische Karte der Schweiz	*various authors* [2]	1972-2014	1:100'000	8
Karte der Mineralische Rohstoffe der Schweiz	*various authors* [3]	1990, 1998	1:200'000	2

SGTK rock collections	Rock types	Sample types	# Samples	Literature
"Die natürlichen Bausteine u. Dachschiefer d. Schweiz"	Construction stones & roofing slates	R. / T.S.	664 / 583	Niggli et al. (1915)
"Mineralische Rohstoffe der Schweiz"	Rocks, metal. ores & hydrocarbons	R. / T.S.	3'683 / 419	Schmidt (1917)
Reference collection of Büro für Bergbau	Metalliferous ores & hydrocarbons	R.	368	Fehlmann (1919, 1947)
"Die nutzbaren Gesteine der Schweiz"	Rock raw materials	R. / T.S.	513 / 259	De Quervain (1969)
"Vorlesungssammlung Nicht-metallische Rohstoffe"	Rock raw materials II	R.	390	-

Fig. 16 (*Top*) The four types of monograph series published by SGTK in the *Beiträge zur Geologie der Schweiz*. (*middle*) Key SGTK Maps and Explanatory Notes. [1] de Quervain et al., (1963, 1964, 1965, 1967). [2] Jäckli and Kempf (1972), Kempf (1980), Jäckli et al. (1985), Pfirter and Hauber (1991), Haering et al. (1993), Pasquier et al. (1999), Pasquier et al. (2006), Hauber et al. (2014). [3] Wenger and Steiger (1990), Cavalli et al. (1998). (*bottom*) Most important SGTK rock collections. Note that the reference collection by C. Schmidt (1917) is stored at the Museum of Natural History in Basel, the others are at ETH Zurich. R.: rock sample, T.S.: thin section. The SGTK monographs *Beiträge zur Geologie der Schweiz* can be downloaded here: https://shop.swisstopo.admin.ch/de/products/publications/geology/contributionsgeo/BGSD

(Figs. 5, 11, 16). Through this series, SGTK promoted new research fields like geophysics and hydrology in Switzerland. For example in 1955, after an unsuccessful request to start a geophysical commission, SGTK recognised the significance of this relatively new field (de Quervain 1974; Pavoni, 1990) and initiated the Geophysical Series (*Beiträge zur Geologie der Schweiz—Geophysik)*. This series was published from 1957 to 1973 by SGTK, and later, 1974–1979, co-published with the Swiss Geophysical Commission (SGPK) that was founded by SNG in 1971 (Fig. 2). This way, SGTK enabled the publication of results from the increasingly important field of fundamental geophysics and geophysical exploration techniques.

Along with the SGTK monographs, maps and books, rock samples were collected, analysed and archived by SGTK at ETH Zurich (Fig. 16). These collections consist of about seven thousand rock samples and thin sections. The most comprehensive and most valuable collections are still stored at ETH Zurich, except the reference collection to the map (Fig. 8) by Schmidt (1917), which is held at Natural History Museum Basel.

The monographs contain a large amount of data on the production and mining sites of geological raw materials in Switzerland. Today, a lot of these data are digitised and georeferenced (> 26′000 locations) thanks to pioneering digitisation projects, which were conducted by SGTK starting in the 1980s (Baumeler et al., 2005; Vogler, 1995; Wenger, 1988). Extracts of the dataset were published in the *Atlas der Schweiz* (e.g. Hurni, 2000, atlasderschweiz.ch). Since 2015, several harmonised geodatasets are publicly available online through the *Resources Information System* map.georessourcen.ethz.ch (Fulda et al., 2018) and as several thematic layers in the swisstopo portal map.geo.admin.ch.

6 A geological survey for Switzerland

The above-described geoscientific activities are in most countries typical survey tasks (e.g. Hill et al., 2020; Lebel, 2020; Smelror, 2020; van Doorn 2012), but were carried out by SNG commissions and their academic members, as Switzerland only established its own geological survey in 1986. The CHF 3′000.- subsidy by the Swiss Federal Council to the SGK for the production of a Switzerland-wide geological map in 1860 represents the first contribution to an SNG commission that was directly coming from a federal office. Earlier projects were funded directly through the SNG, which was at that time financed by membership fees (Seippel, 1900). Therefore, this mapping project can be considered the first Swiss geological survey activity. The SGK and SGTK remained the major Swiss institutions for geological research and national data acquisition and thus together represented a survey-like organisation from 1860 (1899, respectively) until the establishment of the Swiss Geological Survey in 1986 (Westermann, 2009).

In the late 1940s and early 1950s, the Swiss universities and SNG asked for a restructuring of the scientific funding mechanisms to legally anchor national science funding not only for ETH Zurich. As a result, the Swiss National Science Foundation (SNSF, Fig. 2) was founded in 1952. With that, SNG significantly lost importance as large research grants were no longer granted to its commissions, but directly to the university members through the SNSF. This led to a shift towards more fundamental research in Switzerland. As a consequence, also SGTK's funding structure changed. Although a successful memorandum by SGTK in 1958 resulted in a budget increase, fund raising remained difficult. Therefore, SGK and SGTK suggested in 1970 to the Swiss Federal Department of Home Affairs to extend and professionalise the geological survey activities in Switzerland (de Quervain, 1974; Nabholz & Spicher, 1973). They proposed a new Swiss Geological Survey steering committee to be responsible for the three geoscience commissions SGTK, SGK and SGPK. Except some increase of funding for those commissions, this renewed inquiry was not successful. A few years later in 1975, the Federal Council (temporarily) settled the geological survey activities by a decree regarding the funding of the SNG (BR, 1975). The long-wanted geological survey was not established, however, the decree's article 2 states that "the geological and geophysical surveying will be continued by the Geological (SGK), Geotechnical (SGTK) and Geophysical (SGPK) Commissions until the planned reorganisation of this activity on behalf of the Confederation". In 1964, the SGK and SGTK founded a joint Collection Point for Geological Documents (*Schweizerische Sammelstelle geologischer Dokumente*, later renamed into *Schweizerische Geologische Dokumentationsstelle* SGD, Fig. 2), that was incorporated in 1986 into a new federal institution, the Swiss Hydrological and Geological Survey (*Landeshydrologie und -geologie* LHG) as main division of the former Federal Office for the Environment (*Bundesamt für Umweltschutz*, Torricelli, 1967, Nabholz & Spicher, 1973, Heitzmann, 1991). With that, after more than 100 years of federally sponsored geoscientific research, Switzerland had finally institutionalised its geological surveying. However, compared to other European countries, funding for the geological survey activities was relatively low (Hill et al., 2020). In 1999, LHG became a section of the new Federal Office for Water and Geology FOWG (*Bundesamt für Wasser und Geologie* BWG). In 2006, the FOWG was dissolved and the LHG was split. The hydrogeology part was included in the new Federal Office for the Environment FOEN (*Bundesamt für Umwelt* BAFU), and the hard rock geology part became the Swiss Geological Survey as part of the Swiss Office of Topography swisstopo. SGTK and the two other geoscience SNG commissions continued to exist. Unlike the other SCNAT commissions, SGTK had an office with staff employed at ETH Zürich, funded mainly through federal offices. SGTK and SCNAT representatives assumed that, from a tax point of view, SGTK can be treated as a federal institution and thus no VAT was paid on the main funds received from federal offices. After a VAT review in 2016, the Federal Tax Administration concluded that this funding and employment structure of SGTK is not VAT free because SCNAT legally is a private corporate entity. Additional VAT in the order of 250 kCHF had to be paid and, as a consequence, SCNAT dissolved SGTK in 2018. The Department of Earth Sciences (D-ERDW) at ETH Zurich decided to keep the personnel (involved also in the departments teaching program) as an associated group, and integrated it as the Georesources Switzerland Group (*Fachgruppe Georessourcen Schweiz* FGS). This new group is mainly sponsored on project basis by the Swiss Federal Office of Topography swisstopo and D-ERDW and still is in a consolidation phase. It conducts applied georesources research in close collaboration with the Swiss Geological Survey at swisstopo. This includes collecting and compiling fundamental geological data and data related to the use of the mineral and energy resources of Switzerland. With the dissolution of SGTK, the georesources surveying, that SGTK has done for the federation, is today done exclusively by the Swiss Geological Survey. Today, the survey's tasks are clearly defined. It represents the federal competence centre for the collection, analysis, storage and provision of geological data and is responsible for the coordination of Switzerland's geological activities with the cantons, the private sector and universities (LGeolV, 2008; swisstopo, 2017).

7 Discussion and conclusions

This historical overview highlights the key turning points in Switzerland's georesources survey activities. Georesources research in Switzerland gained importance in the early nineteenth century. A solid basis was laid with the foundation of the SNG in 1815, and the SGK and SGTK in 1860 and 1899, respectively. However, it took the Swiss Federation 170 more years to found a national geological survey organisation covering both the geological mapping and the georesources investigations of the country. Compared to most other European countries, it took

Switzerland much longer to create a geological survey and the present-day survey activities are still relatively confined. One reason for this could be that the administrative entities in Switzerland are numerous, small and too diverse to form a geoscientific survey at a "national" level. The absence of larger metallic ore and hydrocarbon resources and a poorly developed mining sector might have been other key factors for the late development of a geological survey. In other countries, a national law (e.g. mining act) gave the government a legal basis to invest in a centralised, state-of-the-art geological expertise and to store relevant data in public repositories. Although the focus of geological surveys changed many times during the last 1–2 centuries, their core tasks remained the same. They (1) manage the subsurface data, (2) interpret these (today digital) data for applied purposes and (3) disseminate the resulting knowledge and products (i.e. maps, models, data portals).

The foundation of the geological and geotechnical commissions as national institutions tried to overcome Switzerland's strongly federalistic organisation (with 25 cantons at that time) by pooling the geoscience expertise for its applied raw materials research. The first two SGTK presidents (U. Grubenmann, P. Niggli) were highly renowned ETH professors and rectors. Geosciences were well-represented at the federal research institution (ETH Zurich) at that time. However, the development of the annual SGTK funding during the first half of the twentieth century does not confirm that apparently important status of SGTK. It remains unclear why a substantial budget increase to a fivefold fixed contribution by the Federation was only reached in the early 1960s. This change of the financial situation coincided roughly with the strong diversification of the research. Nevertheless, many of the landmark comprehensive SGTK monographs were produced during the early period under the direction of U. Grubenmann and P. Niggli, and thus with much less funding available. From the 1970s onwards, SGTK publications reflect an increasingly diverse research focus (Fig. 11). This coincides with faster changing presidencies and the associated loss in continuity and longevity of applied research projects (Fig. 12). In addition, digitisation of the various datasets on mining sites (e.g., Vogler, 1995) and the production of the Hydrogeological Maps (Fig. 16) became an increasingly important topic. Eventually, the diversification of research topics could also be related to the advent of new exploration and analytical techniques, and to more diverse and specific raw material requirements at that time. In conclusion, this diversification reflects a general trend towards smaller and more applied projects in a broad range of geoscience and geoengineering fields, and away from national long-term investigations. This is probably also related to a general, international trend in which fundamental research is progressively detached from applied research.

What remains after these 120 years of applied research on Swiss raw materials by SGTK? Like for geology in general, the specialists of the nineteenth and early twentieth century left us very detailed and comprehensive documentations of geology and geological resources. These rock collections, digital archives and nicely illustrated monographs still form a solid basis to study, visualise and further investigate the spatial distribution and quality of the Swiss georesources.

Today, typical tasks of a geological survey are distributed to different Swiss Federal Offices (i.e. Federal Office of Topography swisstopo, Swiss Federal Office of Energy, Federal Office for the Environment). The Swiss Geological Survey at swisstopo is the main coordinator for geosciences enabling and organising investigations on Switzerland's geology including its natural resources. Most of SGTK's legacy is today taken over by the Swiss Geological Survey. The survey's activities are still broadly supported by SCNAT commissions such as the SGK and the SGPK, but also by the FGS located at a federal university (ETH Zurich).

One of the key challenges for our society today is to reduce atmospheric carbon emissions: On the one hand, this involves exploration of new energy, i.e. deep geothermal resources that involve integrated geological and geophysical approaches. On the other hand, this involves a sustainable handling of the country's mass mineral resources such as cement raw materials (limestones and marls), gravel, sand and hard rock aggregates. Here, geoscientific data represent a crucial basis for decision-making regarding the extension of existing, or the opening of new extraction sites. Knowing the spatial distribution of relevant occurrences is essential for debating the societal and economic choice between local production of cement or concrete with minimal transport distance and thus reduced CO_2 emission and highest environmental standards versus importing the mineral resources and closing the local cement plants and/or gravel pits. The transition to a greener, more carbon-lean economy, including renewable energy production, is increasingly reliant on the access to a growing number of georesources like metals and minerals for (e.g. copper, rare earth elements, etc.). The energy transition strongly depends on the supply of these materials from the subsurface. Not only material extraction is an issue. In order to protect or reinstate the landscape with its ecosystem and subsurface, new land use strategies are needed. Today, about 3% of all anthropogenic greenhouse gases are emitted from drained peatlands (e.g., Leitfeld & Menichetti, 2018). Restoring (i.e. re-wetting) them will significantly help reducing carbon emissions. The Swiss Geological Survey, together with the cantons, the private sector and the universities, is the main responsible for the coordination of Switzerland's geological activities and plays a key role in the transformation process into a more sustainable society, by providing comprehensive and consistent information. This is necessary to support the management, modelling and research of the subsurface for example for the exploration of deep geothermal energy or carbon capture storage. In order to complete these tasks, the federal administration can and should benefit from a tight collaboration with the Swiss universities and with new generations of geoscientists, as it was done in the case of the SGTK.

Supplementary Information

The online version contains supplementary material available at https://doi.org/10.1186/s00015-022-00410-3.

Additional file 1: High resolution version of the map by Letsch et al. (1907) shown in Fig. 6.

Additional file 2: High resolution version of the map by Niggli et al. (1915) shown in Fig. 7.

Additional file 3: High resolution version and full extent of the map by Schmidt (1917) shown in Fig. 8.

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Authors' contributions
SH designed the study, compiled the literature, drew the figures and wrote the manuscript. LN and MV helped to design the study and helped to significantly improve the manuscript. DF helped compiling the literature. All authors read and approved the final manuscript.

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