A Recording Experience

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Abstract: The paper deals with the experience of documenting large industrial sites. The preservation of large industrial sites in situ is rarely an option. Alternatively, an industrial site can be subjected to documentation, in order to achieve some forms of preservation by record. Preferably, industrial sites are best understood while in operation. Practical and methodological considerations in choosing adequate approaches to process recording, as well as the experience of documenting both a living industrial heritage in the form of a mining site in operation and an abandoned mining site in decay are discussed with reference to a pragmatic approach to documentation of industrial sites.

Key words: Process recording, documentation, industrial heritage, preservation.

1. Introduction

In 2002, the Norwegian Mining Museum took an initiative to carry out a comprehensive recording project on a mining site in operation. We were inspired by two projects: (1) the work done by Brian Malaws of the RCAHM (Royal Commission on the Ancient and Historical Monuments of Wales), recording the Taff Merthyr Colliery in Wales; (2) the work done by the NARE (Norwegian Antarctic Research Expedition) 1989/90 in recording abandoned whaling stations on South Georgia. With a small staff with little or no experience from fieldwork, this was a challenge. The museum had previously carried out only minor industrial archaeology projects on mining sites from the 16th century. Documenting mining operations posed a problem. However, we were committed to a task reiterated in government policy documents: Museums should give higher priority to the documentation of the present and near past, especially the industrial development of the 20th century. As a national museum for mining, we had a special commitment in this respect, as no mining sites had been subjected to documentation from a cultural and historical perspective. In fact, the documentation of the industrial heritage in Norway was and still is in its very beginning. Regarding this as a pioneer project, the initiative reflected a learning desire as well. To acquire and improve our skills, the practice of recording and field techniques was an important motivating factor.

The object chosen for our project was the mining site of the company Titania AS. Situated in the southwestern part of Norway, this mine had been worked since 1960. Titania AS is a modern mining company operating an open-pit mine on the Tellenes ilmenite ore deposit, one of the largest in the world. The mining company produces black ilmenite concentrate for the European pigment industry. The ore dressing taking place at Tellenes is a complex and demanding process, involving several recovery technologies. We wanted to do a process recording of this large and complex mining site focusing on the production process, considering this the essential element in industrial life. Although an industrial production process involves several aspects, the form of process, recording we wanted to carry out, was defined to the physical production line in the open-pit mine and the ore dressing plants.

With limited resources, the chosen method was a so-called pragmatic approach to the documentation of industrial sites. This approach has been developed in...
connection with the NARE project, and it offers a more inexpensive, realistic and simplified sets of methods than the more ambitious and comprehensive approaches advocated by the RCHME (Royal Commission on the Historical Monuments of England) and HABS/HAER (Historical American Buildings Survey/Historic American Engineering Record) [2]. These approaches are more suited for traditional antiquarian methods for recording of buildings and architectural history buildings survey than industrial sites in operation. The method is a combination of mutually explicable recording techniques, such as site plan and measured drawings of plans and sections, photography including serial photography, inventory and interviews on specific themes with employees. To what extent was this methodological approach suitable for a process recording of living industrial heritage?

By direct observation in the field, the aim is to collect broad and systematic information and to provide an interpretation of the particular site or the production process involved by creating an archive consisting of written, illustrative and visual material for storage and future use. “The purpose of data collection is not to test scientific hypotheses but to illuminate broad historical issues” [3]. A documentation recording is usually part of a research agenda. However, our project was not. It was part of a priority by the initiating organization to create cultural and historical relevant material for research and presentation in museums and cultural heritage work. This perspective was an ideal for many museum employees at the start of the new century. We should leave the dead collections and dreary registers facing the real world, documenting the social, cultural and industrial changes, addressing our own times and make documentation of the living cultural heritage. For museum-political reasons, as well as for reason of establishing closer contact with the industry we serve, the ambition of documenting one of the remaining mining companies in Norway in operation was an obvious one.

Also within the field of cultural preservation, the idea of documentation of the industrial heritage, instead of physical preservation of buildings and structures, had got political acceptance on ministerial level. The white paper Living with Cultural Heritage establishes a fundamental precondition in this regard: “The physical preservation of old production equipment from industry together with building structures is only possible on a limited scope. In connection with replacement or closure of industrial enterprises, an alternative to protection will be to record objects being removed” [4]. The documentation of industrial heritage sites should thus form a basis for information and knowledge regarding the evaluation and the management of the heritage, and it will in turn provide important source material for scientific research and later industrial archaeology projects. In Norway, with very limited resources and public funding of the cultural heritage, physical preservation of large objects or industrial sites is simply not an issue. The only viable alternative is to carry out a cultural-historical documentation project of the structure or the site in question, in order to achieve a degree of “preservation by record”.

2. How to Do Process Recording?

The recording of an industrial site demands resources, personnel, skills, money and equipment. Limiting factors for us were especially personnel and funding. As a small institution with limited funds for national surveys, we had to pool personnel resources from our own museum and a regional museum, four to five museum curators, for a couple of weeks in the field during the summer season. A grant of 100,000 NOK (Norwegian Krone) from the Norwegian Arts Council, under the post “extraordinary tasks in museums”, provided a basic funding. As an institution with limited time and resources, we had to choose a more effective and flexible approach for the recording of an industrial site. The alternative at hand was a so-called pragmatic approach to the documentation of industrial sites. Gustav Rossnes at the Directorate for
Cultural Heritage developed this approach together with Dag Nævestad at the Norwegian Maritime Museum for the recording of abandoned whaling stations on South Georgia, within the NARE 1989/90 [5]. This approach represents a more realistic, simplified and perhaps adequate set of methods and techniques. The pragmatic approach to documentation is inspired by social anthropology and social history. The interest centers on how the production process is organized within structural settings and aspects of social life and work processes within this context [6]. Thus, the focus is on the functional relations of sites, buildings and rooms, regarding physical context, layout and their social use in order to trace the different stages of a production process.

We also had to consider the aim and thus the level of recording. The aim was easy to define but difficult to operationalize. The mining site at Tellenes with the main aspects of the production flow in the mine and the ore dressing plants were the key production sites.

RCHME distinguishes between four levels of recording. Level 1 involves a quick overview survey of the site based on inspection, resulting in a brief report, with filled in registration forms, some sketches, location map, visual record of exteriors and a short assessment of condition. Level 2 involves a descriptive and interpretative documentation of a site based on field work, providing qualitative information beyond basic data, such as full description and photographic record of buildings and structures, sketched plans combined with analysis of the site with regard to origin, development/changes and use, resulting in a comprehensive written report. Level 3 survey entails an analytical record based on fieldwork and archival work. It requires substance and quality in description and interpretation. It involves graphic description and interpretation beyond Level 2 by measured plans and elevations, a site plan, together with dimensional sketches of detail descriptions of both the interior and exterior of buildings and structures. It involves incorporating an account of the origins and development of the site based on an examination of the site together with readily available sources, as well as a complete photographic record. The written report should be a comprehensive description and interpretation of the site, supported by systematic photographic record, a systematic set of drawings, plans, elevations and site plan, geolocation and map. Level 4 involves an integrated and multidisciplinary recording of buildings and structures of special importance and draws on the full range of sources of information. The report should include a discussion of the object’s significance in terms of architectural or economic history, with regard to projects for physical reconstruction or restoration.

As each industrial site is unique, demanding individualized attention, these procedures were regarded as guidelines and general “modus operandi”, realizing that limited skills, work force and time would make hard choices and priorities in the field necessary. The task of making informed decisions about what to record, at what level and for what reason is proved to be rather demanding.

3. A Suitable Object?

Our ambition was to record the industrial process of a mining enterprise in operation. Historically, Norway had a significant mining sector but a decline set in during the 1960s, accelerating in the 1970s. The drastic decline of mining industry left us with only two ore mining enterprises in operation: (1) Rana Gruber AS (1937, iron ore) in the North of Norway; (2) Titania AS (1916, ilmenite ore (FeTiO3) in the South).1

The Rana Mines, owned by the entrepreneurial firm LNS (Leonard Nilsen&Sønner Eiendom AS), is one of Norway’s largest companies in mining and iron ore beneficiation. Currently, over 1,000,000 t of hematite concentrates and 100,000 t of magnetite concentrates are produced annually. Special products, such as iron oxide pigments (black and red pigments based on micronized magnetite), are produced by a subsidiary

1Http://www.kronostio2.com.
company RG Mineral AS, under the trade name COLORANA.

The Titania Company, owned by Kronos Worldwide, Inc. (in 1989, NL Industries, Inc. organized its TiO₂ operations under its majority-owned subsidiary KRONOS Worldwide, Inc.), mines the world’s largest ilmenite ore deposits in southwest Norway and produces ilmenite concentrates for the European pigment industry, as well as magnetite and sulfide concentrates. Currently, nearly 900,000 t of TiO₂ concentrate are produced annually, a third of that is shipped to the ilmenite smelter Tinfos Titan&Iron at Tyssedal, producing high grade titanium slag and special pig iron. Most of the ilmenite concentrate is exported to Kronos Titan’s plants in Leverkusen and Nordenham, Germany, leading manufacturers of titanium dioxide pigments (TiO₂), a pigment for providing whiteness, brightness and opacity, used in paints, plastics and paper.

With a production of about 1,000,000 t of concentrates each and a staff of 200 (Rana) and 300 (Titania) employees, respectively, the two mining enterprises are insignificant in an international context. Nevertheless, in a Norwegian or Scandinavian context, they represent significant mining enterprises with a long and very interesting history.

The ilmenite mine of Titania was an obvious choice for us: being the largest mining enterprise in Norway and possessing a very interesting site with over hundred years of mining activities and with production taking place in a large and complex ore dressing plant. In addition, it is very important as well: We managed to establish very good relations with the management of the company, showing a genuine interest in having their story told and their site recorded.

At the start, we did not fully realize that documentation is by nature selective and interpretive. Some general problems are addressed. How can the interplay of constitutive elements involved in open-pit mining provide an interpretation of the working of the Tellenes mine as a production system? In addition, how can the combination of mineral processing methods provide an interpretation of the ore dressing at Tellenes as a specific production system? The intention was to interpret the mining site and the production processes in a social context, using a broad social history perspective in order to understand and explain the significant aspects of the site. This perhaps rather naive approach was not developed further by subsequent theoretical reflection or specification of perspective.

4. Change of Plans

During the planning process of our recording project, the question of a demolition permit for the mining enterprise’s old mining site arose. Titania AS had operated the site at Sandbekk from the start in 1916 to 1965. Most of the site was an industrial ruin, and the mining company wanted to dispose of it, as part of negotiations with the Ministry of Industry for a renewed concession. A renewed concession required a permission from the local authorities to demolish the old mining site. A debate on the use of derelict industrial sites arose. Some voices in the local community wanted to preserve the site for industrial tourism and cultural events. Representatives of regional and national cultural heritage authorities suggested that the site should be preserved as a ruin, i.e., the site should be kept (not preserved) in its existing state and be allowed a natural (not controlled) decay. The view of preservation of industrial heritage by allowing a natural decay was new and controversial. However, the voices for industrial tourism or for natural decay did not argue based on a systematic, authoritative or competent evaluation of the preservation value of the site in question. As a national museum of mining without a say in the matter, we kept a neutral stance in the debate.

Nevertheless, it was obvious that, in order to preserve or make the site accessible for the general public, additional money on safeguarding would be essential, which the mining company did not want to spend. The option of a site in natural decay—accessible
to an interested public—would also involve renewed security measures and money, to which the company was unwilling to pay. The preservation of the site as a ruin would have meant extension of fences and security measures both on the site and inside the buildings, as well as some general maintenance. Even minimal security measures would make the buildings in question inaccessible to visitors. Besides, in our view, the decay had progressed too far for any form of preservation. The only realistic option seemed to be demolition, regretfully as it may be. Eventually, the mining company, the municipality and the museums came to an understanding. The historical and cultural significance of the old mining site should at least be subjected to documentation project. All parties were interested in having the site recorded before it was handed over and demolished. Thus, the idea of “preservation by record” was introduced and an emergency recording on our part was hastily designed.

Our point of departure was now quite different. We had a fully integrated mining site, abandoned and mostly not in use, as object. We were to record an industrial ruin with empty buildings and most of the machinery and equipment removed—and no production process. We had to deal with the typical situation of having to record whatever is possible and as good as possible before it is all lost. The tables were turned and our initial interest are reversed; The recording of a living industrial heritage, in form of an actual production process, was replaced by a “dead” industrial heritage with no process.

In a Scandinavian context, it is rare to have a comprehensive mining site standing as a ruin. Usually, sites are demolished with the lapse of the concession. It is rather unique to have such an industrial ruin more or less intact. The museums cooperating in the project were so fortunate as to have full access to the Sandbekk site, as well as to the company’s archives, drawings and names of working people retired. We were asked to select this site as the object for our first major documentation project, transferring the pragmatic approach to the new site [7]. The underground workings, as well as the ore dressing plant, closed down in 1965, while the workshops and office building were in use to the 1980s, some of which are still in use by independent firms. In its heydays in late 1950s, Sandbekk was a large and significant mining site in Norway. For us, the site at Sandbekk had become an industrial ruin of special interest (Fig. 1), and the crash project was launched.

5. What Have We Done?

Through a simplified and structured modus of work, we have obtained information by observation in the field and by documentary research in order to create an archive. The field techniques have been surveying procedures/Measured drawings, photo documentation, inventorying procedures, as well as interviews and oral history.

Measured drawing involves surveying of site, buildings, rooms and floors in order to make a site plan—a site plan of the actual area—as well as plan drawings of each building, room and floor with basic information, as well as one cross section of each main building. The aim is to map the building complex, indicate the different elements of the production process and show the relation between the production line and the plant’s design. Based on this, a building analysis and interpretative flow sheets should be made.

![Fig. 1 The ore dressing plant at Sandbekk before demolition.](Source: PØØ/BVM)
Systematic photography is meant to supplement the other techniques and convey special relations, state, details and context. This means photography of every building or installation (exterior), every room or floor (interior), every machine or piece of equipment (overview and detail), work places, work processes and central elements of the production process, as well as architectural details with note of direction in a photo journal and each motive correlated in the reference system.

Inventory is the structured listing, specification or description in schematic form of material, building methods, type of rooms, deployments and fittings, technical equipment, machinery, working stations, etc., meaning to explain the drawings and supplement the photographs.

Interviews are an integral part of any fieldwork. Through interviews on the site and along with the other methods, valuable information and understanding can be obtained, especially about complicated issues, specific features of the production process and aspects of social history. Oral history usually provides the main source for the interpretation of the site as a workplace and the specific company culture.

6. Results at Sandbekk

6.1 Measured Drawings

We did not have time, skills or equipment for a full survey and measurement of the ore dressing plant complex. Thus, the ambition of a three-dimensional drawing of the building complex was abandoned at the start of the project. A full reconstruction based on archival drawings was not possible due to lack of plans. Thus, measured elevations, cross-section of the main buildings, sections to illustrate vertical relationships and three-dimensional projections of central process elements were neglected, at no excuse. By reproduction of cross-sections in the written report, based on original drawings, this deficiency was to some extent compensated. Nevertheless, our limited skills regarding building recording precluded any illustrations of the structural and special arrangements of the complicated production process. Using a laser distance meter, plans of principal floors and galleries were squared, and floor configurations and structures, like machinery and foundations for equipment indicated, are presented in the form of simplified plans using CAD (computer-aided design). This gave us several good measured drawings (Fig. 2a). As many floors were stripped of machinery and production equipment, some rooms were presented as empty squares. Concentrating on floors, the measured drawings give a simplified outline of where the production process took place and where the workers tending and supervising the process moved. The drawings are nevertheless inadequate and too little detailed in order to support a substantial social history interpretation of the production process and working conditions at Sandbekk. For a site plan, the company’s site plan from 1938 was copied and used. Some work was put into this, and we managed to present a simplified explanation of distinctive relationships between buildings and structures of the site and their functions. An interpretative drawing or flow chart based on a simplified reconstruction of the official flow sheet from 1957 was also developed, as no processes were traceable by measuring survey. A lot of work was put into the schematic diagram, reflecting our problems in the field. We had to focus on learning the basics of the technical aspects or the flow dimensions of the process in order to understand it and record it. The interpretative drawing in the form of a simplified flow chart of the ore dressing process thus became rather technical in character, neglecting an interpretation of the process in a social history context. Thus, lack of time and skill on our part resulted in inadequate measured drawings regarding the ore dressing plant. A copied site plan and a simplified flow chart do not complement this imbalance (Fig. 2b).

6.2 Photography

We carried out intensive photography, focusing on
Fig. 2  Measured drawings of the plat tables section: (a) simplified cross section of the ore dressing plant; (b) Ill: CAD Partner.
external views, exteriors and external details relevant to design, development and use of all buildings. Attention to the structure, layout and relationship of building to setting was paid. Overall interiors and interior detail, especially structural, of all rooms were also photographed. All fixtures, equipment and remaining installations and machines in rooms and stories have been captured, with special attention to functional relations of the objects. With no processes to record, emphasis was put on showing the structures and framework in which the production processes took place. By photography, we managed to cover functional and referential aspects of buildings rather than traditional structural and architectural aspects. Remaining installations, components and machinery were covered both as objects with details and in relation to building, structure and other installation. The intention was to cover the layout, position of machinery to building and other components and their functional relationships (Fig. 3). This was achieved to some extent. Because most of the equipment in the ore-dressing plant had been removed, only a partial and rudimentary recording of the production line could be made. Problems of complication and lack of connections or production-flow elements were legion. Remains and what was left of details regarding the production process were photographed, covering the existing conditions of the ore dressing plants adequately.

Thus, only parts of the framework for the production process and parts of the production line were recorded, while the whole system with all elements and specific arrangements of the production process itself, for obvious reasons, was not.

Systematic photography was given priority in our survey. This provided a fast and effective coverage of the existing conditions of the site. Buildings and structures were captured in a detached and matter of fact style with only small deviations into the esthetics of industrial decay. With our system of reference, measured drawings and photography were connected in a reader-friendly way in the written report, complementing site plan, plan and section drawings, as well as interpretative drawings. Seen together, an adequate description of buildings and structures as framework for the production process is given. For an interpretation of the uses and changes of buildings in relation to the production process, further original drawings and archival studies will be necessary.

In the old mine, only a small part of the ore loading installations and parts of the transportation system were accessible for recording. We managed to get some good shots of a locally adopted loading bench in the crosscuts, while the remaining impressive system of adits and galleries for transportation was almost impossible to capture by photo. Thus photography in the closed mine was proved to be of limited value, just visualizing some scattered mining details and the remains of miner’s rest and eating quarters.

6.3 Inventory

Inventory in the form of a verbal description in a structured schematic form of materials, building materials, use of the premises and the function of equipment and machinery present was carried out for every room and every building (exterior and interior) at the site. In the inventory, our lack of knowledge of ore dressing process technology and industrial construction was overcompensated in the form of verbal description. An inventory is meant to
complement drawings and photographs regarding the documentation of buildings. The result was nevertheless incomplete and insufficient for a full documentation of the production process. The (non-existent) production process could only be subject for a historical reconstruction, mostly based on documentary research.

6.4 Interviews

We interviewed about 20 former employees working in different departments of the mining company. The interviews were invaluable for the understanding of specific functional relationships and the complexity of the whole production process. The interviews have been transcribed, and a brief summary of the information is included in the description of the site in the written report. The oral history project produced useful material for our understanding of working conditions and the social environment of the site in question. Nevertheless, limited objectivity of the oral history material makes it difficult to write a synthesizing analysis of social systems at work and the specific company culture [8].

7. The Sandbekk Site

The construction of the Sandbekk site was completed in 1936 when the mining company opened up the Storgangen deposit for underground mining. Although Sandbekk had been the center for mining activities since 1916, it can be described as a fully-integrated mining site from the mid-1930s.

7.1 The Storgangen Deposit

The Storgangen deposit contained about 70,000,000 t of ore in all. The ilmenite mining at the Storgangen deposit started in 1916 (a small open pit worked at hand power in the period from 1916 to 1935) and mechanically worked from 1935 to 1965. In this period, more than 12,000,000 t of ore containing 17~18% TiO₂ were produced, accounting for 11~13% of the world production of TiO₂ [9]. Mining was based on comprehensive underground workings, consisting of a main adit for railway transportation, a communication drift and transverse drawings drifts for every 28 m. Mining was first based on shrinkage stoping. The ore was loaded in wagons through moveable machine loading benches of the company’s design and transported out of the mine on railway using battery locomotives. Compared to modern standard, this was small-scale production, amounting to about 750,000 t of ore per year in late 1950s. The mining department was the largest and most significant section of the company, employing about 100 miners at the most.

In the written report, an interpretation of the development of mining methods underground is given in a broader sense. In the first period (1935~1945), the company adopted the state-of-the-art mining system at the time—shrinkage stoping. The mine was distinctive regarding size and complexity of the underground exploration, comparable to the largest mining enterprise in Norway at the time, the pyrite mine of Orkla Grube-Aktiebolag at Løkken Verk. In the second period (1945~1955), a mining method specific for the company was adopted—a combined method of drift stoping and open-cast mining. The method was based on time and method studies carried out during the occupation period, anticipating a situation of increased demand and mine catch with fewer men. The combined method also involved the introduction of removable, specially designed loading machines, as well as hard metal drilling, resulting in a 50% increase in the total output of the mine. In the last period (1955~1965), a method of vertical long hole top-slicing was adopted. The method was state-of-the-art technology at the time, adopted by many mining companies. The method increased security, as well as extraction, enabling Titania to reach the maximum of mining catch, while pioneering the introduction of health and safety regulations in the mine.

7.2 Building History

At Sandbekk, three successive ore dressing plants
were built. The first (and quickly redesigned) ore dressing plant was completed in 1919, a second plant was erected in 1931, and the third ore dressing plant was completed in 1936. The 1936 work was part of a comprehensive expansion scheme, enabling the mining company to increase its exports. The company were to deliver 50,000 t of ilmenite concentrate to the new plant of the Titanium Pigment Company Inc. at Sayreville, New York. Machine engineer E.B. Mölbach, who had supervised the construction of the British Titan Products Ltd.’s plant at Billingham, designed the new ore dressing plant. The ore dressing plant was placed beside the main adit in a sloping hill, utilizing the height levels for organizing the ore dressing process based on gravity separation and magnetic properties of the existing minerals—in the classical way. The different sections for grinding, washing on shaking tables and magnetic separation were situated on floors, step by step downwards in the works. The plant was constructed in reinforced concrete for foundation and floors, clad bricks in steel structures and profiled steel plates for walls and a tin roof, making the working conditions unbearable during hot summers and freezing cold during winters. The ore dressing plant was state-of-the-art plant construction of the mid-1930s. It functioned satisfactorily from the start and was characterized as “a first-class work” [10]. The ore dressing plant was designed for a capacity of 70,000 t ilmenite concentrate. The works were eventually improved, expanded and reconstructed to sustain a capacity of over 200,000 t of concentrate in the late 1950s, while the work force in the works remained on the level of about 30 men.

7.3 Production Process

The interpretation of the production process in the works had to be a reconstruction of some sort. The reconstruction could not be based on photography or measured drawings. It had to be based on documentary sources, secondary literature, schematic diagrams, previous flow sheets and oral history. The written report presents a predominantly technical interpretation of the production process (Fig. 4).

Initially, the ore dressing plant at Sandbekk received about 60 t of ore per hour. The ilmenite ore contains, on average, 35~40% ilmenite and 5~10% magnetite, with the chemical content of about 17% TiO₂ and about 20% Fe. Products were concentrate of ilmenite containing about 44% TiO₂ and concentrate of magnetite containing 66% Fe. The process from crude ore to final concentrates involved on four separation technologies: (1) gravity separation based on shaking tables (90 Deister Plat-O-Tables) in order to produce a bulk concentrate of ilmenite and magnetite; (2) magnetic separation of magnetite from crude ilmenite on 14 magnetic drum separators, working with a Deister Compound Funnel and a Gröndal ball mill in closed circuit; (3) ilmenite recovery by high-intensity magnetic separation on 10 Wetherill-separators; (4) selective flotation of fine fraction by two strings of flotation cells (with Fagergren and Denver cells) from 1953. The variety of mineral separation methods and the scope of the various sections of the ore dressing plant made the Sandbekk work one of the largest and most complex ore dressing plants in Norway.

Crude ore pass the coarse crushing plants in three steps: (1) through a jaw crushe with a Ross feeder; (2) through a 7’ Symonds standard cone crusher medium type with a vibrating screen; (3) through a 5½’ Symons short head cone crusher of fine type with six vibrating screens. Crushed ore with the size of 10 mm was sent to grinding in four rod mills. Water was added to the mills and the ore was grinded down to less than 1.5 mm. The separation process was started with classification of the pulp. The fine ore contained ilmenite and gangue in separate particle size, and mineral separation was based on dividing the pulp flow according to particle size. Through a pulp distributor and via six Deister Compound Funnels, primary goods are washed on 36 Deister Plat-O-Tables. From the coarse fraction tables, three products emerge. The coarsest was disposed of as tailings, the medium product
was sent to further grinding in two rod mills, while the fine fraction was sent to magnetic separation. After dewatering and reconditioning, the medium product was sent to 30 Deister Tables for fine fraction. The concentrate from this step was sent to the magnetite section as well.

Two series of magnet separators of Löwenhielm type received concentrates from the shaking tables, containing about 35% TiO₂ and separating magnetite. Previously, concentrate of magnetite was dewatered in a cone, passed through a Dorrco drum filter and was sent to steel silos and storage at Rekefjord. From 1953, fine fraction from the table sections via a Dorrthickeners, and slime fraction from the magnetic separation of magnetite was treated in a flotation plant. The froth from the flotation cells containing ilmenite was cleaned three times. Concentrate of ilmenite was filtered and mixed with the concentrate from the Wetherill-separators. Non-magnetic fractions from the magnetite section containing ilmenite was dewatered, filtered, and dried in a rotary kiln, 21-m long. The ilmenite concentrate (38% TiO₂) was cooled and conveyed to a section of 10 high-intensity magnetic Wetherill-separators. The finished ilmenite concentrate containing about 44% TiO₂ was sent to a separate ilmenite bin and then by cableway to silo and loading facility at Jøssingfjord.

In the written report, a social history interpretation of work processes in the ore dressing plant is described in brief. The main activity of the workers, now called
process operators, was tending, controlling, overviewing and adjusting an almost fully automatized process. Exclusively recruited from the local community and without professional skills, they relied in short on the job training in order to understand the flow line and “read” sections of the production process in which they were to intervene. There was a variety of smaller and larger tasks, most of which were routine, like opening a tap, adjusting a tube, collecting a sample or removing a block-up. They worked in a very noisy environment, often alone, minding the faultless running of the process with little or no chances for social interaction while on shift. Competent, loyal and dutiful workers were earning the respect of other through their work ethic.

7.4 Company Town?

The Sandbekk site was a fully-integrated mining site with railway and towline transportation systems, for magnetite concentrate and ilmenite concentrate, respectively, locomotive shed, compressor house, silos, loading installations, various workshops, laboratory, office buildings, storehouses, dwelling houses and a welfare building. In the 1950s, the mining company was a self-sufficient industrial enterprise producing and maintaining most of the production equipment by their own, employing over 400 workers. The mining company Titania AS was a pioneer regarding workers’ safety and welfare, symbolized by the sophisticated welfare building with a miners’ bath from 1936 and the new welfare building with a hall from 1954. In that decade, Sandbekk constituted one of the four largest mining sites in Norway. Nevertheless, Sandbekk never developed into a mining town or a company town like Løkken Verk (1904: Orkla Grube-Aktiebolag; 1987: Orkla Industrier AS) or Sulitjelma (1891: Sulitjelma Aktiebolag; 1983: Elkem AS). This was because there was little/no industrial or infrastructural concentration beyond the mine and work place at Sandbekk. Mining workers and employees lived in and around the commercial and communication center at Hauge i Dalane, 5-km off.

8. Results at Tellenes

8.1 Measured Drawings

The aim of measured survey of buildings is to map and show relations among the production process and building structure and the arrangement of space. The result should be a site plan relating buildings to others structures, including topographical features and various areas of activity, as well as a three-dimensional presentation of the main buildings. For our part, resource constraints made the use of these techniques impossible. How to measure so large structures and buildings, even if a Total Station was available, which was not the case? It would have taken unjustifiable long time to carry out measured surveys of all buildings, levels and rooms. A measured survey of machinery and production equipment in a place where the production process is so complex, especially where flows divide and re-join in closed circuits seemed to be an insurmountable task. Even as a separate exercise, this would involve a lot of time, money and skills, none of which we had at the time.

Giving up making of measured drawings of site and buildings meant that important themes as building history, subsequent changes in the production process and an interpretation of work situations in a social history context had to be left out. The Tellenes site shows interesting aspects regarding building history and comprehensive redesign of the production process. These developments should have been covered in a diachronic building analysis and sequential site plans of the flow line. These developments will not be presented in the form of drawing sets, but they will be commented in an essay interpreting the building history of the Tellenes site in the written report.

The situation forced us to adapt a level of recording appropriate to available resources, i.e., corresponding to Level 2 in the British tradition. The technique of measured drawings was replaced by a detailed and verbal account of the production process, tracing the
process sequence by sequence, complementing the account with photographs and inventory. Priority was given to the creation of interpretative drawings of the three main ore dressing plants. These drawings go beyond orthographic views to clarify, explain and emphasize distinctive relationships between physical features of the buildings and the production process. We hired a firm to make simplified CAD-drawings of the three works, using existing plans from the company archive, as well as the official flow sheet. The 3D representations represent a reconstruction, as the basic building dimensions are correct. Nevertheless, equipment and machinery have been abstracted to symbols, and architectural features and supportive engineering features of the plants have been excluded. Striving for clarity of the production process lay-out, cross references to measured drawings and photography was neglected. Thus, two aims were achieved: (1) “measured” building plans of the main structures showing the layout of production equipment and machinery, although in a rough and simplified way; (2) a CAD-sketch of the production process with main flows and productions lines, showing the relevant functional relations in general.

What was lost by this solution was two-fold: A cross-section of buildings and structures, especially site profiles, important in mining landscapes, particularly ore dressing floors that rely on gravitation for their flow systems, was neglected [3]. Measured survey or checking of actual building and productions line features in relation to original plans in order to record alterations, adjustments and rebuilding, an important demand regarding documentation of industrial structures was also missed. Facing large structures, compromise regarding measured survey seems inevitable. In our view, exact measured surveys of large and complex industrial buildings would create information in excess, information useful for architectural restoring or scientific research but not relevant for a general understanding of the layout and functions of a production process at the mining site. If the company in question can provide building plans, a reconstructed and explanatory 3D presentation of main buildings and production process sequences should suffice (Fig. 5a).

8.2 Photography

By photography, three-dimensional qualities, space, elevation, texture and arrangements will be recorded. Nevertheless, in large and complex structures with intrinsic production lines, problems of congestion and the complexity of components of machinery and equipment mean that only a limited number of elevations, details and process sequences can be recorded. Photography can hardly record adequately the variety of elevations and functional relations in large buildings packed with production equipment high and low. Photography is adequate for the recording of

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**Fig. 5** 3D reconstruction of the flotation hall at Tellenes: (a) interior of flotation hall; (b) illustration: CAD Partner AS. Source: HH/BVM.
settings and arrangements in a context, but it has limitations regarding the abovementioned details and functional relations.

Serial photography is a necessary part of all process recording. Nevertheless, it is difficult to carry out systematically. In the actual ore dressing process characterized by several flows, flows separated and re-joined in closed circuits, pumps, hydro cyclones, re-pumping, various pipes, as well as three-fold mineral separation processes, serial photography fails to record adequately flows, functional relations and sequences of operations in the production line. Moreover, important aspects of the production process, such as flows, fluidity, noise, smell and repetition, require other visual recording methods in order to be adequately captured (Fig. 5b). A meticulous recording would have produced information in excess, information difficult to arrange and present in a comprehensible manner. Consequently, we had to reduce the level of detail, focusing on settings and context, doing more of a reconstruction and simplification of the production process than the factual recording of it. We found it necessary to supplement the field techniques by the use of video recording, in order to capture texture and plasticity of the production process in a more suitable way.

Photography is well suited for the documentation of the human and social aspects of production. Attention should be given to how work is executed and manifestations of the workers’ existence as individuals, in self-created “social spaces” or “personal corners” at the work place. Nevertheless, working processes in the ore dressing plants in question are not spectacular. Work is mostly tending, controlling, monitoring processes, sample-taking and supervision, carried out by one operator, not collectively, in front of a computer screen, a control panel or a specific control spot in the works. Traces of the “human touch” are scarce, almost non-existent, except for some illustrative examples in some of the control rooms.

We started the photography using Kodachrome 200 slides 35-mm black and white film. This was recommended with regard to having the best storing qualities. During the last field season, all photographic documentation was done digitally. The use of large format (5” × 7”), the HABS/HAER standard, was out of the question for us on economic grounds [11].

8.3 Inventory

We carried out a rough inventory, by verbal description in a structured schematic form, of buildings, machinery and equipment and the set-up of the production flow. The focus was on important production machinery, installations and equipment, as well as the general layout of the buildings. It was a general inventory; Equipment is referred to by name in daily use, not by firm, fabrication type and technical

Fig. 6 Interior of the crushing and milling hall (above), exterior of the ore silos and crushing and milling plant at Tellenes. Source: FS/BVM.
specifications. Fixture and building details are subjected to a general listing, rather than a specific technical description. Again, attention was given to functional relationships between buildings and the layout of the production process, rather than the details of the machinery and production equipment themselves. This brief, verbal and structured recording is not suitable with regard to a full documentation of working processes. Some of the most relevant aspects of the work process will be covered in the general description of the production process in the subsequent written report.

For large structures, a database application would be suitable for the keeping and seeking of large quantities of information. We could not afford the time use of preparing and collecting of large amounts of data. In our assessment, a complete and specific description of standard equipment, fixtures and building details would produce little information value. We had to renounce with respect to level of quality and detail in order to keep the basic information in schematic form and integrate the inventory with photography in the form of a photo journal and the site plan through a consistent system of reference. Thus, the inventory can be used as a general, descriptive and explanatory supplement to interpretative drawings and photography.

8.4 Interviews

Interviews of employees at Tellenes have been done sporadically so far. Formal interviews of operators during work hours were not suitable. During documentation work, I personally talked with several operators, asking them to explain the production process in detail for me, as well as asking them on their usual tasks, their training, professional competence, the work environment and social relations within the company. These talks, often during the night shift, have given us important information, guiding us in the carrying out of the documentation. The informal talks contributed greatly to the understanding of the production process and gave us some fundamental insights into the ways and workings of the mining enterprise. In my experience, the operators showed a keen interest in telling about their work and skills. They were open and forthcoming in telling about their work life. A sense of pride on their part caused by working in a sophisticated ore dressing plant and being employed by a company characterized by excellent industrial relations, seemed genuine. A central theme in subsequent formal interviews can be attitudes to and experiences of professional qualification schemes. A preliminary observation is that, although the level of formal education is low among the operators, most of them have been through a process of qualification, earning the title and certificate of “process operators”, a trade qualification equivalent to operators in metal processing and chemical industry, as well as in the oil industry in the North Sea. In fact, process operators at the Tellenes complex compare themselves to colleagues in the oil industry, claiming that the demands of knowledge and skill, vigilance and precision, understanding of complexity, processes and specifications, as well as continual and accurate supervision, in fact, was greater at the Tellenes ore dressing plants than in the ordinary oil industry.

We consider interviews to be the main documentation method for covering the elements of social history related to an industrial site. The ambition is to describe the specific social environment of the industrial undertaking. The challenge is to develop adequate concepts and analytical tools in order to make an interpretive analysis of practices, attitudes and social relations within the work force. In this respect, we still have a way to go.

9. The Tellenes Site

The Tellenes site lies 5-km southeast of Sandbekk, and mining activities have been carried out in an open pit mine since 1960.

9.1 The Tellenes Deposit

The open pit mine was in 2005, 1,600-m long,
600-m wide, with a depth of 190 m and a total of ore production of about 7,000,000 t annually. From 1960 to 2004, altogether 166,000,000 t have been taken out, about 100,000,000 t ore and 70,000,000 t of waste rock. Ore contains 17–19% TiO₂. The Tellernes ore body is probably the largest individual titanium deposit in the world, containing approximately 15% of the world’s reserves of titanium. In 2005, the company had plans for the mine for 20 years ahead. In the autumn of 2007, a new section of the mine was opened for production, with a time span of 65 years ahead. The estimates of total ore reserves are for nearly 200 years [12].

Drilling on 15-m high benches is performed by one rotary drill GD-100, with a rotary drill BE-55R as stand by, drilling 17–18 m blast holes, 12¼ in. in diameter. Usually, 60–120 m per shift are drilled, 1 t of explosives per hole used, and 50–70 holes per blast prepared. For the weekly blast 50–100 t of slurry are used, giving about 200,000 t of total output per blast. For loading two hydraulic shovels, one rope shovel P&H1900 and one front-end loader are used. For transport of ore to the primary crusher one unit-rig MK36, two unit-rigs MT3600 and three Caterpillar789B&C with payload 177 t are used. Each blast is mapped, samples-taken and content-analyzed, and the selection and distribution of the specific ore qualities carried out according to customer’s demand, involving a sophisticated planning and distribution process. Generally, after having passed the primary crusher (gyratory), the crude ore is transported on belts to two mountain silos, according to grade of chromium content.

9.2 Building History

The construction of the ore dressing plant started in 1957, after the mining company got a concession to mine the giant Tellernes ore body discovered in 1954. The American owner at the time, National Lead Company (from 1971 known as NL Industries) wanted to build a simple, one-size ore dressing plant close to the coast and limit investments to a minimum. The Norwegian management of Titania, supported by the technical and mining consultants Anders Sandaker and Worm Lund, respectively, had their way in an alternative solution. A solution based on superseding the difficult landscape conditions and organizing the main steps of the ore dressing process in separate buildings, utilizing the downward gradient of the landscape. The coarse crusher was placed on the top of the open pit, at the limit of the ore body, connected with a 300-m long tunnel to the crushing and mill hall situated in the slope of Hommedal (Fig. 6a). A large flotation hall, 17-m below in the valley, was built, connected through a 3-km long tunnel carrying pipe lines to the drier hall, placed on a level of 80-m below, situated on a hill top 140-m above sea level, excellent for two vertical silos excavated in the mountain beneath. The Tellenes Lake covering part of the ore body was divided with a dam; The eastern part was drained, while the western part was used as a reservoir for production water. The three main buildings were constructed in reinforced concrete with shell roof, designed by architect Henning Astrup in Neo-Functionalist style. The Tellenes complex was built for a capacity of 300,000 t of TiO₂ concentrate annually, but it was designed to take a triple fold increase in production capacity. At the opening of the Tellenes complex in 1960, managing director Robert Brun, hailed the simplicity, boldness and geniality of the consultants’ solution, calling it all a “monumental work” [13].

9.3 Production Process

Mineral separation or ore dressing takes place in three large works or halls, geographically and topographical separated from each other. The ore dressing process is an intricate and complicated one, involving three main separations processes: gravity separation, magnetic separation and flotation, as well as leaching and sulfide flotation. The final products are ilmenite concentrate containing 44.3% TiO₂, between 600,000–900,000 t per year, magnetite, containing
60% Fe, about 10,000 t a year and sulfide concentrate, containing some 5% Ni, 2% Cu and 30% S, about 5,000 t per year.

In the crusher and mill hall, the first step is crushing and grinding of the crude ore in two steps, crushing in two medium cone crushers followed by fine crushing in four smaller cone crushers. The particles are less than 12 mm and are transported to a row of milling silos. From here, the ore is sent to ball mills, water is added, and the ore is grinded down to less than 0.5 mm, the mills working in closed circuit with filters and a hydro cyclone. At this stage, crushing and grinding have produced grains consisting of just one mineral. After grinding, magnetite is separated on a set of magnetic separators and a ball mill working in closed circuit. The magnetite is then transported to “the drier” for sulfide flotation (Fig. 6b).

After magnetic separation of the magnetite, the non-magnetic pulp stream is classified in three fractions, the coarse fraction is processed by gravity separation in a section consisting of Reichert cones and spirals. The fine fraction is sent through a high intensity wet magnetic separation process, using a Sala High Gradient Magnetic Separators, and the finest tailings are sent to the land deposit by way of dewatering installations. The fine fraction from desliming and classification in hydro cyclones are separated by high intensity wet magnetic separation, and the concentrate from this second mineral separation process is sent to ilmenite flotation in the flotation hall.

The ore dressing plant was originally built for flotation as the major mineral separation method, but gravity separation was introduced in 1983 in order to be able to better cope with the variety of ore qualities. Through sets of conditioners, flotation cells and thickeners, a concentrate of about 43% TiO2 is produced. Concentrates from gravity separation and ilmenite flotation are sent to the drier hall for special flotation.

“The drier” constitutes the last element of the ore dressing process (Fig. 7a). The ilmenite concentrate is subject to leaching and sulfide flotation. This “inverted flotation” in order to rinse the ilmenite of its phosphorous content as well as to wash out pine oil together with sulfides, was originally a significant innovation developed by the company’s previous head for research and development, Dr. Olav Mellgren. The sulfides in the magnetite concentrate are removed through a similar process. Sulfides from the two processes are subject to sulfide dewatering in a thickener before the sulfide concentrate is sent through a horizontal vacuum filter to the sulfide silo, a silo blasted out in solid rock beneath the drier works.

Ilmenite concentrate is dewatered in thickeners and a series of vacuum filters before taken through rotating gas-heated kilns where the moisture is reduced to 3.5% water. The final product is sent to two large storage silos with a capacity of 80,000 t in the mountain beneath the works and taken on transportation belts to waiting ships in Jøssingfjord. Magnetite concentrate is dried in a dewatering cone and a vacuum filter before being sent to the magnetite silo, previously used as the ilmenite storage silo from 1936 (Fig. 7b).

The handling of tailings in two large thickeners before the fine sand is sent to a large land deposit is a final part of the ore dressing process. A laboratory of their own with advanced equipment helps to ensure continuous quality control throughout the process.

The Titania AS company has a separate quay and shipment installation in the Jøssingfjord serving about 150 calls per year.

9.4 The Titanium Industry

Ilmenite concentrate serves as a raw material for chemical and metallurgical industries. For the chemical industry, ilmenite concentrate from Jøssingfjord is shipped to Kronos Worldwide, Inc. owned plants at Fredrikstad in Norway, Leverkusen and Nordenham in Germany, manufacturing Titanium dioxide (TiO2) pigment called Titanhvitt (Titanium White), a pigment with high opacity, brilliant whiteness and excellent covering power. Manufacturing is based on the sulfate
process, a production process invented by the founding fathers of the Norwegian titanium industry, Dr. Gustav Jebsen (1884–1951) and Prof. Peder Farup (1875–1934) in the years of 1914–1916. Titania AS is a main supplier for the part of the European pigment industry based on the sulfate process. For the metallurgical industry, TiO₂-concentrate is sent to intermediate processing, pre-reduction and smelting, at the ilmenite smelting works at Tyssedal. Here the company Tinfos Titan&Iron (since 1986) delivers a yearly production rate of 200,000 t of titanium slag (78% TiO₂), used in the sulfate process, and 110,000 t of special pig iron, used in motor blocks, car parts and other casting material due to its low content of pollution elements [14]. Thus, the titanium industry is “Big Stuff”, both in a Norwegian context as a large mining site and in a European context as a supplier of raw materials for the pigment industry. Norway is the fourth largest producer of Titanium minerals in the world [15].

9.5 A Modern Mining Company?

Titania AS is as a modern mining company, with over 100 years of experience. In the last decades, it has entered into a somewhat stagnating phase. It is a very resource-based enterprise, controlling one of the largest ilmenite ore deposits in the world, with 400,000,000 t of ore reserves. There is no need for ore exploration, no urge for developing new processes or products and no interest in investing in order to optimize the production potential. Main challenges for the company are competition from the new chloride process, a lower-cost, more efficient and safer method for processing TiO₂. Nevertheless, it manages to keep a position among customers using the traditional sulfate process. The level of production is dependent on deliveries to the Tyssedal plant, but this has turned into an unstable nexus. In addition, as the Tellenes ore have the lowest TiO₂ content on the world marked; opening of new ore deposits thus pose a threat. As Titania AS supplies a key raw material to the TiO₂ pigment production process on a long-term basis, a real asset for KRONOS Worldwide, Inc., dependency on sales to third parties, makes marked prospects uncertain. The company has a long history of research and development of products and production processes. However, the latest development of ilmenite concentrate as a weight material for the oil exploration industry have received moderate interest. Because of operation in a high-cost country, focus has been on continued improvements regarding process technology and raising the professional level of the work force. In the mine as well, the year 2012 marked a 10-fold increase in production capacity since opening the Tellenes ore deposit, mining machinery that is among the largest and most modern in Europe.

Titania AS has now a core staff of 290 employees, 17% of whom are female.
10. Some Final Thoughts

In 50-year time, the building complex at Tellenes will probably be obsolete and ready for demolition. If civilization, as we know, still exists, the mining activities here will be continued. Nevertheless, the mining site represents an important part of our modern mining heritage. We may state that the site demonstrates the functional relationships of a modern mining enterprise in an illustrative way, enhanced by the specific geological landscape called the Rogaland Anorthosite Province, where parts of the landscape has been drastically transformed by mining activities through 150 years. The site is highly representative for the design and construction of industrial facilities in the post-war and reconstruction period of Norwegian history from 1945 to 1965, as well as an excellent example of how the topography has been integrated in the physical layout of the ore dressing plants. The best reference in this respect will be the mining sites and ore dressing plant of the iron ore mining company AS Sydvaranger at Kirkenes, where a post-war reconstruction and expansion was completed in 1956, influenced by the aforementioned consultants. The building complex at Tellenes has also an architectural value, highly representative for late, industrial Functionalist style and design from the heyday of Modernism in Norway.

Nevertheless, these arguments for the site’s historical, cultural and architectural values will probably be regarded as unconvincing, weak and apart. The general practice, at least in the hydro-electrical power supply and mining sectors, regulated by specific clauses in the concessions granted by the Ministry of Trade and Industry, has been the demolition of plants and standing structures no longer in use. Most likely, there will be no argument for the preservation by law of the industrial site when it is eventually decommissioned.

In the future as of now, preservation of large industrial sites in situ, especially at remote places far from urban centers, will still simply not be an issue. The outcome of a decommissioning will probably be demolition, just as in the case of the Sandbekk site. At Sandbekk, the sale of the industrial ruin was not realized. The mining company, having obtained a demolition permit from the municipality, started planning for a successive demolition of the old ore dressing plants in progressive decay. Demolition was started in 2011 and was completed in spring 2014. All buildings and structures connected to the production process at Sandbekk had been removed. The days of Sandbekk as a fascinating industrial ruin was over. Most of the physical remains of a once vigorous and proud mining site had gone. Only the main entrance (not original) to the mine, some sheds and the old and new laboratory, will bear witness to the mining activities here. The remaining workshops, storehouses and administrative building are not representative for the mining site per se. Nevertheless, from the stance of preservation of the industrial heritage, the situation is not quite miserable. Although the option of a preservation of the site by natural decay did not prove to be a viable one, the site has at least been subjected to a documentation project and thus preserved in archival form.

It is impossible to tell what will happen with the building complex at Tellenes in the future. Fortunately, that is not for us to decide. For the Norwegian Mining Museum, the only realistic alternative for preserving some of the mining heritage at sites like these is through a cultural and historical documentation project. We have tried out the so-called pragmatic approach for documenting the industrial heritage. First, a rush recording of an industrial ruin at Sandbekk has been done, reconstructing the production process of the past. Then, we did it by carrying out a predominantly visual documentation of buildings, machinery, equipment and work situations, as well as the production process in the mine and at the ore dressing plants at Tellenes. Whether this way of documenting the two mining sites is an adequate way of “preservation by record” of dead and living industrial heritage is up to others to decide.
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