Feasible Mining Technologies for Placer Titanium Mines in Vietnam

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Abstract - Vietnam has a potential reserve of placer titanium. The reserve lays in sandy beaches along the country from Thanh Hoa to Binh Thuan province. Placer titanium mines in Vietnam are different in geological condition, the scale of production, mining method, and environmental protection solutions, etc. Some of them are operating with inappropriate mining technology; therefore, have caused environmental issues and ineffective operation. Based on categories of geology, the scale of production, mining characteristics, requirements of safety, land reclamation and environmental protection, and mining effect, authors 3 most feasible mining technology for coastal titanium placers in Vietnam, including: (i) Mining technology with excavators and trucks, processing by spiral screws, and discharging mud by pumping; (ii) Mining technology with hydraulic jets, suction and hauling by pumping, processing by spiral screws, and discharging mud by pumping; (iii) Mining technology with ore pumping, processing by spiral screws, and discharging mud by pumping.

Index Terms - Feasible mining technology, placer titanium mie, Vietnam

1 TITANIUM PLACERS IN VIETNA

Titanium placers in Vietnam, are found along the coastal line from Thanh Hoa province to Binh Thuan province (Fig. 1). Results from prospecting and exploration show the industrial value coastal titanium placers are located mostly in the marine sediments (m), formed during the Middle to the Late Pleistocene, and in the marine - wind sediments (mw) of the Middle to the Late Holocene, which the length is from hundreds of meters to 20 kilometres, the width is 25-700 m, and the thickness of 0.5-10 m (Quach D. T. et al., 2012).

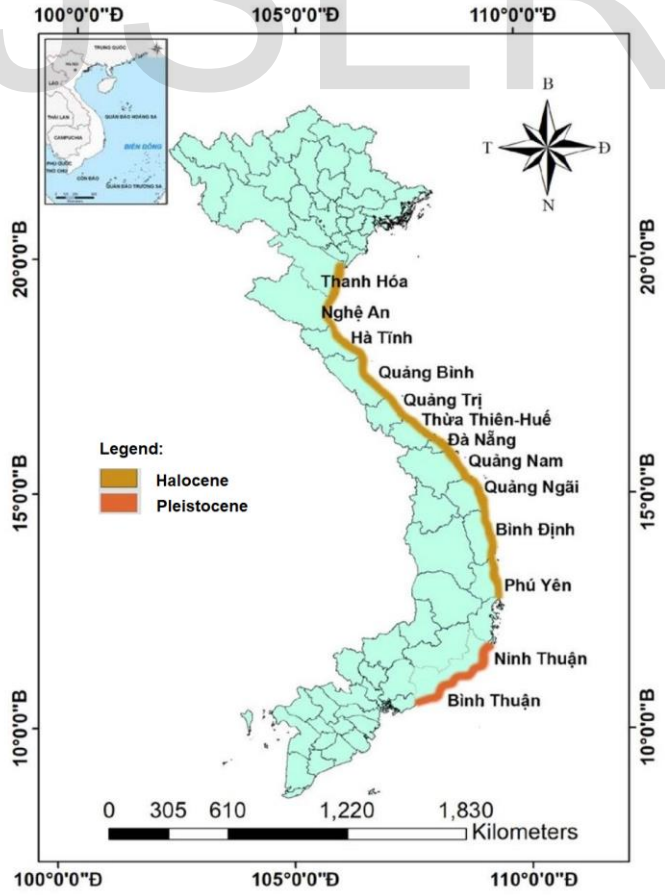

Fig 1. Location of titanium placer deposits in Vietnam (Le Qui Thao, 2020)

The coastal titanium placers in this country have similar features with sediments titanium placers in the world. They are synthetic placers, deposited by minerals with a density of 4.3-5.2 and grain size of 0.047-0.25 mm. The majority of useful minerals comprise ilmenite, rutile, zircon, and monazite in which the content of ilmenite, zircon, and rutile is 53.09-91.66%, 3.56-18.45%, and 0.69-2.65% respectively (Quach D. T. et al., 2012).

The extracted ore from the titanium placers is qualified for export requirements. Titanium is an important mineral which is used widely in various industries. Vietnam is considered a potential country in the world thanks to the big reserve of approximately 650 Mt (Tab. 1) (Luong Q. K. et al., 2016). To date, coastal titanium placers are extracted in 23 mines from Ha Tinh to Binh Thuan in Vietnam (Tab. 1).

Tab. 1. Overview of coastal titanium placers mining in Vietnam (Vietnam Department of Geology and Minerals, 2018)

No	Mine	Province	Areas (ha)	Reserves (tons)	Output (tons per year)
1	Ky Khang	Ha Tinh	759	1,567,000	64,700
2	Cam Xuyen	Ha Tinh	1,595	1,019,000	68,000
3	Sen Thuy	Quang Binh	382.8	217,596	13,000
4	Dong Luat	Quang Tri	75.2	121,189	143,100
5	Vinh Tu	Quang Tri	118	102,283	8,413
6	Hai Khe	Quang Tri	241,8	172,293	10,000
7	Gio Linh	Quang Tri	156.83	66,206	5,560
8	Quang Ngan	Thua Thien Hue	288.2	376,305	30,000
9	Phu Dien	Thua Thien Hue	90	568,735	31,500
10	My Thanh 1	Binh Dinh	242.8	736,732	52,500
11	My Thanh 2	Binh Dinh	173.26	326,076	26,250
12	My Thanh 3	Binh Dinh	179.92	322,110	24,150
13	My An	Binh Dinh	180.69	179,454	14,000
14	Nam De Gi	Binh Dinh	150	334,597	35,000
15	Tu Hoa - Tu Thien	Ninh Thuan	1,132.5	3,929,646	199,500
16	Son Hai	Ninh Thuan	1,033	3,329,312	118,904
17	Thien Ai 1	Binh Thuan	64.5	44,617	3,186
18	Thien Ai 2	Binh Thuan	356.45	218,000	24,000
19	Vung Mon	Binh Thuan	23,968	90,049	11,025
20	Long Son – Suoi Nuoc 1	Binh Thuan	807.2	2,234,875	213,900
21	Long Son – Suoi Nuoc 2	Binh Thuan	156.4	378,994	43,490
22	Mui Da	Binh Thuan	224	148,069	70,000
23	Nam Suoi Nhum	Binh Thuan	515.5	2,343,159	117,345

2. THE CURRENT EXPLORATION OF TITANIUM PLACER IN VIETNAM

2.1. Mining scheme using excavators (wheel loaders) and trucks, in combination with the fixed processing complex

In this scheme (Fig. 2), ore is loaded by excavators or wheel loaders to trucks for transportation to the fixed processing complex that is located in the centre of the mine, and the mixture of sand and water is pumped into the primary process system. The concentration ore collected from the primary process is reprocessed in the concentration processing component to obtain the required concentration ore (of approximately 85% of heavy minerals).

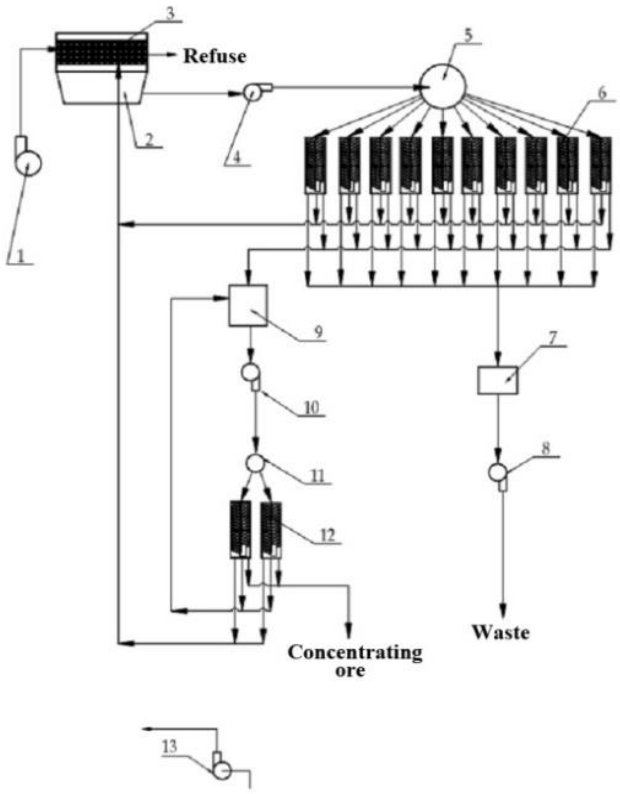

Fig. 2. The flowchart of the process scheme with the fixed processing complex (Bui X. N. et al., 2016)

where: 1- Feeding pump of run-off mine ores, 2- Tank for collecting run-off mine ores, 3- Screen for separating refuse, 4- Feeding pump for primary processing component, 5- Feeding tank for primary processing component, 6- Primary processing component, 7- Tank for waste sand, 8- Pump for removing waste sand, 9- Feeding tank for the secondary processing component, 10- Feeding pump for the secondary processing component, 11- Tank for dividing into flows, 12- Secondary processing component, 13- Water pump.

2.2. Mining scheme using hydraulic jets and pumps, in combination with raft-mounted mobile processing complex

This scheme is used for sediments below the underground water level. In this scheme (Fig. 3), the ore bodies are broken by hydraulic jets (if necessary) and pumped to the raft-mounted mobile processing complex of the mine for separation into three kinds of products (tailings, intermediate ore, and concentration ore). The intermediate ore from the primary processing is pumped to the secondary processing to get the concentration ore. The qualified concentration ore (the grade of heavy minerals is higher than 85%) is pumped to the store. Waste sand is pumped to the waste dump in the mined-out areas. The scheme is currently applied in most of titanium placers mines in Vietnam.

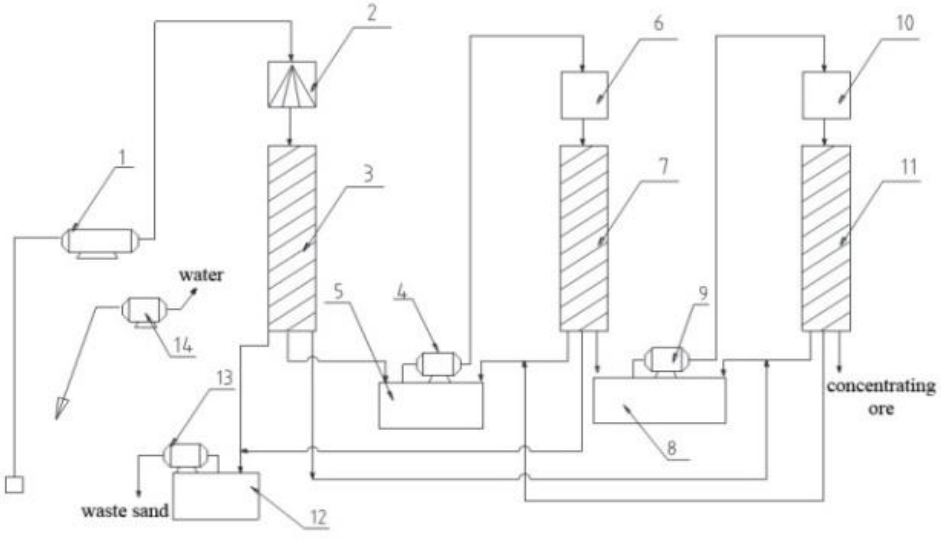

Fig. 3. The flowchart of the process scheme with mobile processing complex (Bui X. N. et al, 2016)

where: 1 - Ore sand suction pump, 2 - Feeding tank with separation mechanism, 3 - Primary processing component, 4 - Intermediate processing pump, 5 - Tank for pumping to the intermediate processing component, 6 - Tank for dividing into flows, 7 - Intermediate processing component, 8 - Tank for pumping to the secondary processing components, 9 - Feeding tank for the secondary processing components, 10 - Tank for dividing into flows, 11 - Secondary processing component, 12 - Tank for pumping waste sand, 13 - Pump for removing waste sand, 14 - Water pump.

3. FEASIBLE MINING TECHNOLOGIES FOR COASTAL TITANIUM PLACERS IN VIETNAM

Beside two above-mentioned mining schemes, based on the geological and hydrogeological conditions, mining condition, equipment used, coastal titanium placers in Vietnam can be exploited theoretically with 9 mining technologies below (Le Qui Thao, 2020):

(1) Mining technology with excavators and trucks, processing by spiral screws, and discharging mud by pumping;

(2) Mining technology with excavators and trucks, processing by spiral screws, and discharging mud by bulldozer;

(3) Mining technology with hydraulic jets, suction and hauling by pumping, processing by spiral screws, and discharging mud by pumping;

(4) Mining technology with hydraulic jets, suction and hauling by pumping, processing by spiral screws, and discharging mud by bulldozer;

(5) Mining technology with ore pumping, processing by spiral screws, and discharging mud by pumping;

(6) Mining technology with ore pumping, processing by spiral screws, and discharging mud by bulldozer;

(7) Mining technology with suction dredger, transporting by pumping, processing by spiral screws, and discharging mud by pumping;

(8) Mining technology with suction dredger, transporting by pumping, processing by spiral screws, and discharging mud by bulldozer;

(9) Mining technology with bucket chain excavators, transporting by belt conveyor or conveyor bridge, processing by spiral screws, and discharging sand by belt conveyor.

However, after studying for specific conditions, derived from the nine above-mentioned mining technologies, the following technologies are feasible for coastal titanium placers in Vietnam. They are:

3.1. Mining technology with excavators and trucks, processing by spiral screws, and and discharging mud by pumping

This mining technology is applied for any productivity of mine that the water supply is not abundant, technological conditions for an internal waste dump are not supportive. An external waste dump which is close to the primary processing station is helpful in this case.

At the primary processing station, sandy ore is separated from the garbage and gravel by rotation screening or inclined vibrating screening, running off to the sandy mud hole afterwards. Sandy mud is pumped to the ore tank of the processing station, continuously pumped to spiral screws. The levels of spiral screws are assembled depending on the separation feasibility of the raw ore and the grade of the useful heavy minerals. A clutch separator can be installed before spiral screws. However, it requires a stable feeding of ore, and therefore, is rarely used due to difficulties in operation, low recovery and promotion of the secondary processing. The output of the processing component is concentration ore and waste sand. Waste sand is pumped into the waste dump through the mud pipeline system. In case water is circulated, the mining tecnology is illustrated in Fig. 4.

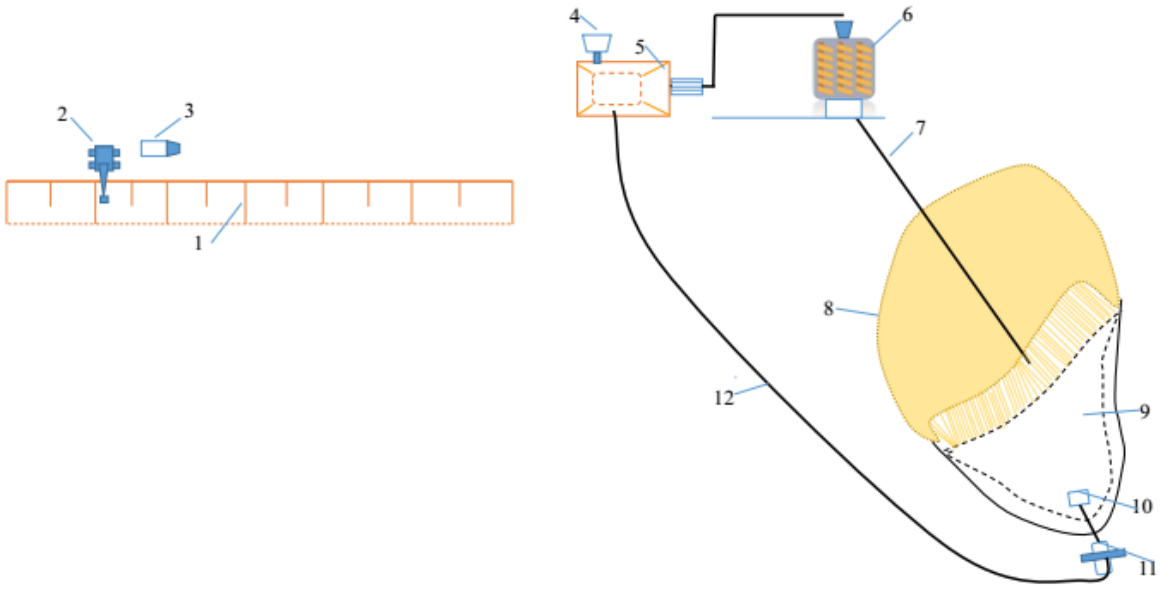

Fig. 4. Mining technology with excavator and trucks, processing by spiral screws and discharging mud by pumping (water circulation)

where: 1- Mine site; 2- Excavator; 3- Truck; 4- Tank with garbage filter mechanism; 5- Pumping mud hole; 6- Spiral scews stations; 7- Mud pipeline; 8- Filled waste dump; 9- Spare waste dump; 10- Water filter well; 11- Water circulation pumping station; 12- Water circulation pipeline.

3.2. Mining technology with hydraulic jets, suction and hauling by pumping mud, processing by spiral screws, and discharging mud by pumping

This mining technology differs from the mining technology with excavators and trucks, processing by spiral screws, and pumping mud by the combination of hydraulic jets and pumping mud. This is the popular mining technology in coastal titanium placers, especially in areas with abundant water resources and difficulties in directly sucked by pumping mud (Fig. 5).

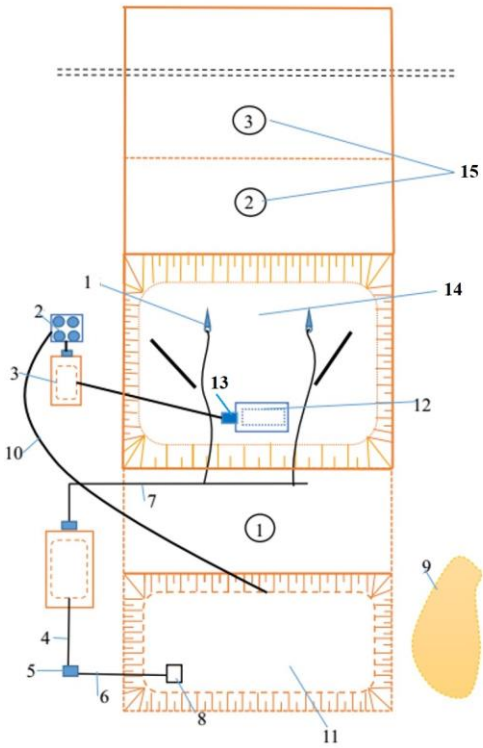

Fig. 5. The flowchart of mining by hydraulic jets, pumping and hauling by pumping mud, processing by spiral screws, discharging mud by pumping (division mining)

(1- Hydraulic jets; 2- Spiral screws station; 3- Feeding mud hole; 4- Water pipeline; 5- Water circulation pumping station; 6- Water pipeline from filter well; 7- Pressure water pipeline for hydraulic jets; 8- Waste dump filter well; 9- Temporary waste dump of the first mining division; 10- Waste mud pipeline; 11- Internal waste dump; 12- Mud pumping hole in the mine site; 13- Feeding pump to spiral screws; 14- Mining site; 15- Mining order of different division).

3.3. Mining technology with ore pumping, processing by spiral screws, and discharging mud by pumping

This is the simplest mining technology, which is used in small titanium placers in white sand seams or grey sand seams that are not thick. In this mining technology, the ore mud pumping is put on the floatation to pump the sandy mud at the lower level and the run-off sand. High-pressure hydraulic jets support to pump into the crest to dilute the mud concentration for a better ore pumping. The ore mud is transported by the pipeline to the primary spiral screws station of the mine site. Discharged sand is pumped into the mined areas by the mud sand pipeline (Fig. 6).

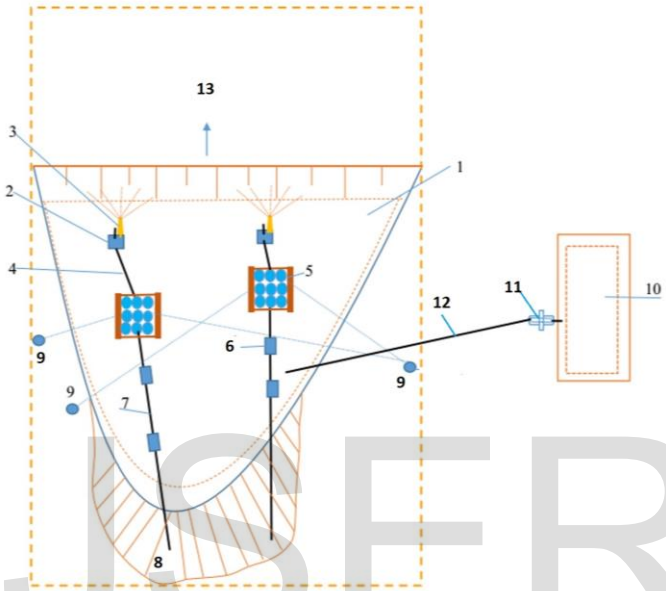

Fig. 6. The flowchart of mining by ore pumping, processing by spiral screws, and discharging mud by pumping

where: 1- Ore mud pumping hole; 2- Pumping raft; 3- Hydraulic jets (if necessary); 4- Ore sand pipeline; 5- Spiral screws station; 6-Floatation; 7- Waste sand pipeline; 8- Internal waste dump; 9- Fixed bolts of spiral srcew station; 10- Backup water hole; 11- Water auxiliary pump; 12- Water auxiliary hauling pipeline; 13- The next mining area.

4. CONCLUSION

Vietnam has a potential reserve of coastal titanium placers. However, mines here have not been effective operating, facing challenges in safety, loss of resource and negative impacts on the environment due to inappropriate mining technology.

The article offers 3 most feasible mining technology for coastal titanium placers in Vietnam, including:

Mining technology with excavators and trucks, processing by spiral screws, and discharging mud by pumping;

Mining technology with hydraulic jets, suction and hauling by pumping, processing by spiral screws, and discharging mud by pumping;

Mining technology with ore pumping, processing by spiral screws, and discharging mud by pumping.

These mining technologies can be applied also for coastal titanium placers in Vietnam and in other mines with similar conditions of geology and hydrogeology for effective, safe and environmental protection requirements.

5. ACKNOWLEDGEMENT

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