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Bio+Mine Project: Empowering the Community to Develop a Site-Specific System for the Rehabilitation of a Legacy Mine

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Abstract

The rehabilitation of legacy mines continues to be a big challenge because of the difficulties in returning them to safe and stable conditions and ensuring that the mined-out areas become productive to support the economic activity of the host community. Previous efforts are often focused on purely technical and environmental aspects, leading to resistance from the local community due to their exclusion from the rehabilitation process. To address the issues associated with legacy mines and lack of participation of the community, we have developed a project, Biodiversity Positive Mining For The Net Zero Challenge (Bio + Mine), focusing on the abandoned Sto. Niño copper mine (Benguet, Philippines). The mine was closed in 1982 without a plan involving local stakeholders and leaving a significant ongoing negative legacy. Using the social-ecological-technological system framework, we will explore the intersections of the structure and functions of socio-economicdemographic, ecological, and technological data useful in devising a more inclusive mitigation strategy for the reconstruction of the supporting ecosystem. We aim to develop a site-specific system, underpinned by the local community's knowledge and practices, that can be a model for wider implementation in other legacy and active mines worldwide.

Keywords

community based research, grounded theory, mixed methods, social justice, ethnography, situational analysis

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Introduction

Mining supplies the metals and minerals that are essential for modern society's development and daily operation. However, the industry is constantly criticised because of its negative impacts on the local community and the environment. A recent review pinpointed more than 630 000 closed and abandoned mine sites worldwide and most of these sites remain unrehabilitated and release hazardous elements into the environment (Park et al., 2019). Because of this negative legacy, new mining projects often face stiff opposition from local communities. For example, in Tampakan, South Cotabato, Philippines, where a large porphyry copper deposit was discovered in 1992, the development of the mine has been stalled for decades because of strong resistance from the indigenous community and local government unit (Middleton et al., 2004; Tabelin et al., 2021).

More recently, the global challenge of limiting the impacts of climate change has placed high premiums for metals, materials and minerals critical for the manufacturing and deployment of renewable energy and clean storage technologies. Decarbonising the transport and energy sectors is a key strategy for reducing CO_2 emissions and arresting climate change. In a recent report by the World Bank Group (WBG, 2020), the demands for 17 materials (aluminum, chromium, cobalt, copper, graphite, indium, iron, lead, lithium, manganese, molybdenum, neodymium, nickel, silver, titanium, vanadium and zinc) are projected to dramatically increase due to the clean energy transition. Copper, for example, is a "crosscutting" metal essential in more than eight renewable and clean storage technologies, and its demand is projected to increase from ~20 Mt in 2019 to ~29 Mt by 2050 (WBG, 2020).

The mining industry is increasingly aware of mistakes of the past and in 2001, the international council on mining and metals (ICMM) was formed to improve the performance of the industry as a whole. Since then, guidelines on community development and leading practices for the management of mine wastes and rehabilitation of mines sites post-closure have been published (ICMM, 2012). Moreover, mining companies have invested millions of dollars in their corporate social responsibility (CSR) programmes for the sustainable development of host communities (Isacowitz et al., 2022). Unfortunately, legislation and policy for responsible mining operations, including environmental and safety regulations are not retrospective and, were either weak or non-existent before the 1980s, leading to operators abandoning closed mine sites and related infrastructures with little or no rehabilitation (Tabelin et al., 2022). Abandoned and closed mining areas with incomplete rehabilitation are generally referred to as legacy mines. These sites are not subject to the increasingly strong regulations so continue to cause problems and exacerbate people's negative views and perceptions about mining (Promentilla et al., 2021). Even if they have ceased operating, they continue to discharge toxic metals from waste dumps, tailings storage facilities, open pits and/or underground mine workings, causing environmental and human health hazards (Coelho, et al., 2011; Monjardin et al., 2022; Tomiyama et al., 2019) and their legacy is therefore negative to both the environment and the local stakeholder community. With such issues associated with legacy mines, government bodies have increased interest for rehabilitation to return them to safe and stable conditions consistent with the surrounding landscape. The ultimate aim of rehabilitation initiatives is to make the land productive to support the economic activity of the host community (Dahlgren, 2022). Previous research on rehabilitating legacy mines focused mostly on technical and environmental aspects with low participation of the local community (Keenan, et al., 2016). Consequently, the rehabilitation programmes were not aligned to the aspirations of the people, and hence, it yielded few or no favourable results and were not sustained (Adam et al., 2021).

To address the issues associated with legacy mines and low participation of the community, we have developed the Biodiversity Positive Mining For The Net Zero Challenge (Bio + Mine) project (https://bioplusmine.earth) that is focused on the Sto. Niño copper mine (Tublay, Benguet, Philippines), where a negative legacy exists. Our project will assess the current legacy issues, and with the local community, we will co-devise a programme of intervention that aims to mitigate problems and to develop processes to recover valuable metals from waste materials for the green energy transition whilst neutralising problematic components. In Year 1, we will deliver baseline data to develop a strategy for the reconstruction of supporting ecosystem services (i.e., microbiomes, plants, and earthworms), including sustainable agri-ecosystems for local communities while increasing the natural capital of the site, natural carbon sequestration and biodiversity that could also be incorporated into a full-scale system of intervention in future years. In Year 2, we will develop site-specific strategies that are underpinned by the knowledge of the local community and practices and will be a model for wider implementation in other legacy and active mines worldwide. In Year 3, we will build the capacity of the community to implement and sustain the site-specific strategies.

Focusing on the Sto. Niño mine as a case study, the Bio + Mine project seeks to make mining projects inherently reconstructive in its plan, delivering the metals for a green economy but rebuilding ecosystem services from the microbiome up to support sustainable use of the sites for local communities. The overarching research questions of the project are:

1) 'What are the requirements (social, technical and economic) that need to be met to ensure the development of successful biodiversity positive solutions in legacy mines?'

    - We will work with local stakeholder communities, particularly with Indigenous Peoples (IPs), to explore their views, perceptions, beliefs, needs and aspirations for a sustainable future for the legacy site. Also, we will explore background information on biogeography and the diversity of an 'ideal' reconstructed ecosystem that will serve as a benchmark for a favoured outcome which, as well as mitigating impact, will enhance the use of nature to mitigate climate change by revegetating degraded mine sites.

2) 'How can the Sto. Niño mine site be explored as a natural laboratory to reconstruct the ecosystem, inform the development of sustainable nature-positive bioremediation strategies, and support ongoing agricultural activities by the local community?'

   - We will further provide the background technical information (both 'geo' and 'bio') needed to outline the challenge faced by the team and inform the development of a programme to implement mitigating and reconstructive actions. We will conduct laboratory and virtual experiments to help define the bio-interventions for the site to support reconstructed ecosystem services. By working with local communities, we will enhance the use of nature to increase the resilience of communities and ecosystems, working on using sustainable nature and ecosystem services to reduce poverty.

3) 'How do we ensure that interventions lead to positive outcomes from a systemic point of view, and how do we quantify the impacts of the identified solutions?'

   - We will test an initial model for intervention leading to a plan that can be costed for potential long-term implementation. There will be an ongoing follow-up to test the effectiveness of an implemented bio-intervention. We will empower the local communities and stakeholders to implement a longer-term monitoring strategy to assess the system's performance. Given favourable outcomes, we will produce a policy paper that will inform 'future positive mining' solutions more generally, identifying suitable further sites for implementing the strategy.

In this study protocol, we only outlined the social dimension of the project. This component answers the following research questions:

1. What are the communities' views, beliefs, perceptions, aspirations, knowledge and skills related to:

   a. socio-economic and environmental impacts of mining;
   b. rehabilitation of legacy mine (both indigenous knowledge and science and technology);
   c. social dynamics and policy needed to support rehabilitation programmes;

2. What social metrics can be used to inform decisions related to the rehabilitation of legacy mine?

Answers to these research questions will provide the social data to inform decisions related to developing the site-specific system to address the legacy mine issues. The methodologies of the other project components (geochemical, geophysical, environmental, biological and mapping) will be reported elsewhere.

Theoretical Framework

To ensure the development of a site-specific system underpinned by the local community's knowledge and practices, we will adopt the social-ecological-technological systems (SETS) framework. The SETS framework is deemed appropriate as it positions the ecosystem services as deeply embedded in the local contexts (Frantzeskaki et al., 2019) and are generated by the intersections of the structure and functions of the three subsystems, (S) socio-economic-demographic; (E) ecological; and (T) infrastructure, technical, and technological (Pickett et al., 2001). Using this framework will ensure that the site-specific system we aim to develop is informed by various data with primacy to using social data. The site-specific system requires all stakeholders, referred to as communities, to co-design the rehabilitation project as part of human, environment, and technology systems and assess underlying social drivers (metrics) and benefits to the community and the environment.

The SETS also informed our approach to working with the communities by adopting a developmental approach. Year 1 starts with **informing** the community about the goal of the project. This is followed by **consulting** them to explore their views, beliefs, perceptions, aspirations, knowledge and skills about rehabilitation and then **engaging** them to build stronger relationships. Year 2 involves **partnering** with different stakeholders to establish collaborative work to address shared goals and objectives of the project. The ultimate goal is **to empower** the community to fully implement intervention programmes in Year 3.

Methods

The methodology described below outlines we will engage with the key stakeholders of Sto. Niño.

Research Design

This research will use the exploratory sequential design mixed-method design (Tashakkori & Teddlie, 2003). This design uses an initial qualitative phase to explore the communities' views, beliefs, perceptions, aspirations, knowledge and skills about mining and rehabilitation of legacy mines. This is followed by a quantitative phase, where the results of the qualitative phase will be used to develop a survey tool to investigate whether the wider communities share the participants' views. In the final step, both the results of the quantitative and quantitative phases will be integrated to answer our research questions.

Study Setting

The study is conducted at Sto. Niño mine in the Municipality of Tublay, Benguet, Philippines. Eight (8) barangays are in the Municipality, but the research area will only focus on Barangay Ambassador, where the Sto. Niño legacy mine is located. Mining claims in the area dated back to 1907 by prospectors J. D. Highsmith, W. A. Ebert, G. Icard, I. K. Prentiss, and A. J. Reynolds, a group who later formed the Baguio Gold Mining Company, the predecessor of Philex Mining Corporation. The company acquired 13 claims in 1932 as well as the Noble and Gibbs claims in 1933. It acquired 12 more claims added between 1933 and 1935 (MGB report, 2019). From 1972 to 1981, Philex Mining Corporation undertook two mining operations: open pit in the Southwest orebody and underground block caving in the Ullmann or Northeast orebody. The site was abandoned in 1982, and since then, the area has been used by the local community for agriculture. For more than four decades, there was no comprehensive rehabilitation programme implemented. The people are aware that significant health and safety risks are prevalent in the area, but they continue to live there and use the land for agricultural purposes.

Participants

We will explore individual communities' contexts, beliefs, perceptions, knowledge base, needs, and aspirations towards the mining industry. This process will ensure that knowledge, skills, technologies, and processes introduced to the relevant communities will appropriately address their specific needs and aspirations. The communities are sub-divided into five (5) categories and described as follow:

1. The host community refers to people (i.e., children, women, men, senior citizens, etc.) living in communities where mining companies operate. They could be further categorised as: those who are dependent on mining for livelihood; the residents who are immediately affected by the environmental impacts of mining operations; and the Indigenous People (IP) community, who primarily experience displacement and other socio-economic concerns.
2. The mining community refers to mining executives, operators, contractors, and workers on the mining site.
3. The LGU and regulatory community refers to the government agencies responsible for the enactment of local ordinances and executive issuances on mining, for instance, the Department of Environment and Natural Resources (DENR), the Mines and Geosciences Bureau (MGB), and the local government unit (LGU) that can directly supervise mining companies since these are within their jurisdictions.
4. The professional community pertains to the police, military, media practitioners, teachers, church leaders, and researchers, who may have direct or indirect involvement in mine operations and mine risk education.
5. Civil society pertains to environmental organisations, advocates, charitable institutions, non-government organisations, and activist networks who are outsiders of the mining industry but aim to protect the environment by monitoring the company's compliance with regulations and mining rehabilitation programmes, to express a strong sense of sympathy for most vulnerable groups within the mining ecosystem, and to preserve the aspirations of the Indigenous groups in the community.

Ensuring Access to the Community

To promote active participation from the community, we employ a technical consultant from the area working with the community and the LGU. He has been involved in many national and international development projects. His local knowledge, including community structure, leadership, processes and local languages, and research skills, helps inform our research activities. To strengthen our engagement with the community, we obtained a partnership with the Tublay LGU and barangay local government unit (BLGU), preceded by obtaining a tripartite memorandum of understanding (MOU) between the research group with both government units. We also obtain certificates from both government agencies stating that their offices interpose no objection to the project. Also, we employed and trained three research assistants (RAs) from the community to help us in the research processes, including translating documents to local languages, interviewing using local languages, and transcribing and analysing data. Any community engagement activities, including data gathering, are checked by the technical consultant and local RAs to ensure that we do not violate any local customs and practices.

Securing a Certificate of Precondition

As we are working with IPs in the Philippines, we must adhere to the Indigenous Knowledge Systems and Practices (IKSPs) and Customary Laws (CLs) Research and Documentation Guidelines of 2012. This is a national policy of the Philippines being implemented by the National Commission on Indigenous Peoples (NCIP) that ensures to "(a) promote, protect and recognise the rights of Indigenous Cultural Communities/ Indigenous Peoples (ICCs/IPs) to cultural integrity and to prescribe protection mechanisms at the international and national government levels and within the context of relevant customary laws; (b) ensure and guarantee the due exercise by the concerned ICCs/IPs of their right to allow or reject, through free and prior informed consent, research and documentation of their IKSPs and CLs and their derivatives; and (c) regulate the use of IKSPs and CLs, and ensure that IPs benefit from the use of research output/outcome" (p.1). Before applying for a permit with NCIP, we conducted an ocular visit in Tublay, Benguet. The Municipal Mayor and other officials welcomed the team. We discussed the proposed research activities with them and sought their support. After, we visited the mined-out area with the help of the barangay captain of Ambassador and Tublay Disaster Risk Reduction and Management Office officer. We also engaged with the Department of Environment and Natural Resources – Cordillera Administrative Region (DENR-CAR), Community Environment and Natural Resources Office, Mines and Geosciences Bureau and Tublay School of Home Industries, to discuss the project goals. We obtained the requirements for permitting from the NCIP and DENR-CAR offices. Based on the policy, we complied with the following steps:

1. Filing of application and payment of fees. Following their template, we submitted our research proposal, including certification of the source of funds, timeline and activities, and our manifestation that the research team will pay for any administrative costs associated with our research. In addition, we submitted an executed affidavit that we would abide by the guidelines articulated in the policy document. The MSD Chief reviewed our documents with the assistance of the Regional Legal Officer. After our documents were deemed sufficient, the Regional Director formed the IKSP team to facilitate the proceedings.
2. Transmittal. The transmittal from the Regional Director was delivered to the community through their IP leaders to inform them of the research project and the Work and Financial Plan (WFP) development.
3. Development of Work and Financial Plan. Our research team worked closely with the IKSP team to develop the WFP detailing the expenses for food and transport for IP leaders and members who will attend the conference, documentation, expenses, and other logistics costs.
4. Conference and Disclosure. Five days after the WFP had been approved and signed, the IKSP team scheduled a conference for the research team to present our research proposal to the community. This was participated by 48 IP leaders and the host community conducted in their community cooperative place. During the conference, a tribal ritual, following the customary practice of offering a live animal and prayer, the tribal chieftain welcomed the team and granted the initial permission for research activities. We presented the research proposal, including the scope, extent of community participation, data needed, and issues that may arise during the research process in the local language. After, the IP leaders accepted the research and identified key signatories of the memorandum of agreement.
5. Memorandum of Agreement (MOA) preparation, Negotiation and Signing. The MOA was negotiated between the IKSP and the research team. We articulated in the MOA the parties involved, the duration of research, the rights and responsibilities of each party, the information that may be disclosed to the researchers, possible restrictions, the benefits for the community, the dispute resolution process, and sanctions for non-compliance of the agreement. The MOA was written in English with translation in their local language, Kankana-ey. After the MOA had been reviewed, it was signed by the IKSP representative and the research team leader.
6. Submission of Report. The proceeding of the conference and MOA signing and the signed MOA were submitted to the Regional Director for review. The Regional Director issued the Certificate of Precondition (Control No. CPIKSP-CAR-2022-017), which we submitted to the institutional ethics committee as part of the document required for our Ethics application.

Part of the process and as articulated in the MOA, we will conduct a community validation activity after the completion of data gathering. The IKSP team will facilitate the activity. The result of the validation shall be contained in a resolution, which will be issued by the community, indicating the authenticity of the data and the compliance of the research team and process to the MOA. A certificate of validation will be issued by the IP representative, indicating their satisfaction with the results. Copies of the research outputs will be submitted to the community registry, NCIP regional and central office, and the NCIP central office library.

Individual Interview

The interview guide (see Appendix A) contains a range of questions framed around social-ecological-technological systems. We outlined the information we need from the community in Table 1. Based on this information, we included questions that explore the community's views, beliefs, knowledge and skills about mining and rehabilitation of legacy mines (People), shared norms that permeate the system (Culture), goals of the system and metrics to assess outputs (Goals), technologies and equipment used within the system (Technology), the physical infrastructure of the system (Infrastructure), work processes and practices (Processes), and physico-chemical biological factors (Ecological). This information will inform the Bio + Mine site-specific system together with the geological, ecological, hydrological, and technological data from other teams.

Survey

The results of the interview will inform the development of the survey tool. The survey tool will cover a range of questions, including participants' demographic profile and their views about mining and rehabilitation of legacy mines. We will follow both theoretical and empirical approaches to tool development. For the theoretical approach, we will follow the following steps as suggested by DeVellis (2003): (1) define the construct to be measured, (2) construct the item pool, (3) establish the appropriate format of the measure, (4) have experts' review the items, (5) pilot test the items, (6) analyse the items, (7) optimise the scale length. We will use the factor analytic approach for the

Table 1. Summary of Data from the Participants.

Community	People	Culture	Goals	Technology	Infrastructure	Processes	Ecological
Host	Views, beliefs, aspiration, knowledge and skills about rehabilitation	IP leadership norms, shared responsibilities and stewardship	Provide information and actively contribute to the project	Indigenous technology	Community infrastructure	Indigenous processes and practices for rehabilitation	Plants, crops, organisms and earthworms Water, soil, weather
Mining	Views, beliefs, aspirations, knowledge and skills about rehabilitation	Integration of rehabilitation plan to their operation	Strong support to the rehabilitation activities	Leading practices in rehabilitation	Infrastructure established to support rehabilitation	Practices in rehabilitation/ CSR	Plants, crops, organisms and earthworms Water, soil, weather
Civil society	Views, beliefs, aspiration, knowledge and skills about rehabilitation	Advocacy movement	Promote social and environmental protection	Approaches used in promoting their cause	Infrastructure established to support rehabilitation	Activities organised and implemented	Plants, crops, organisms and earthworms Water, soil, weather
Professional	Views, beliefs, aspiration, knowledge and skills about rehabilitation	Research and development agenda	Bring new knowledge and technology to the people	Professional services offered, including consultancy and training	Infrastructure established to support rehabilitation	Integration of rehabilitation knowledge and practices in their work	Plants, crops, organisms and earthworms Water, soil, weather
LGU & regulatory bodies	Views, beliefs, aspiration, knowledge and skills about rehabilitation	Policy implementation and accountability measures	Protect the people and the environment	Technology adopted and implemented	Infrastructure built for rehabilitation	Institutionalised rehabilitation processes and activities	Plants, crops, organisms and earthworms Water, soil, weather

empirical approach to establish the tool's psychometric properties (Worthington & Wittaker, 2006).

Sample Size

The total sample size for the interviews is estimated to be 50. Specifically, this sample size is comprised of the following:

1) Host community – 10 from Barangay Ambassadors and two from the seven other barangays.
2) LGU Officials – four from Barangay Ambassadors and five from the municipal level.
3) Professional Groups - 10 teachers, 10 police, and five media practitioners.
4) CSOs - three representatives.
5) Mining operators - five.

For the survey, we aim to have 670 participants as follows:

1) Mining workers – 50.
2) Host community - 150 women and 150 men.
3) Youth – 100 young professionals, 100 high schools, 100 Out of school youth.
4) People with disability – 20.

We will ensure that our participants are mixed gender to have perspectives from a range of participants. The sample size for interviews and the survey are sufficient to meet our research aims and to answer our research questions. The 50 individual interviews will allow us for a rich exploration of the research topic (Bryman, 2016). In addition, the 670 participants for the survey are large enough for any quantitative analysis (Tabachnick & Fidell, 2007).

Recruitment of Participants

Participants will be recruited through the LGU, both at the barangay and municipal levels. Our local RAs will distribute the Participant Information and Consent Form and will consolidate the list of our participants to be interviewed and to respond to the survey.

Risks to Participants

We do not anticipate any harm to the participants. Their participation is entirely voluntary, and they can discontinue participating in research anytime they feel uncomfortable or for whatever reason. Participants will not incur any expenses related to their participation. We will provide cash incentives (i.e., fare, food allowance, and renumeration for their time) for their participation charged to the project funds.

Privacy and Confidentiality

The interviews will be audio-recorded, and no identifiable information will be gathered except for the community they represent. Our research team will transcribe the audio recording. For the survey, demographic information, including gender, age, educational attainment, and years of residence, will be gathered to allow for cross-sectional analysis. Raw data will not be shared with other researchers outside the Bio + Mine team. The de-identified data will be stored for 5 years after the publication of the research findings.

Data Analysis Plan

We will employ situational analysis, following the guidelines of Clarke et al., (2017), to analyse internal and external environments, including elements (i.e., related discourses, symbolic, spatiotemporal) to identify opportunities and challenges for the rehabilitation of Sto. Niño mine. Analysis of the interview data will follow the six steps outlined by Braun and Clarke (2006). First, we will familiarise ourselves with the data by re-reading it several times. Second, the first and second authors will independently generate codes and collate data relevant to each code. Third, we will search for potential themes and organise the codes based on the themes. Fourth, the first and second authors will review the themes, focusing on similarities and disagreements. Any disagreements will be discussed, and in cases where the disagreements cannot be resolved, two other research team members will be invited to help resolve the issue. Fifth, the themes will be named. The ongoing analysis will refine each theme's specifics and the overall narrative. Each theme will be clearly defined. Finally, the final report will be written. Interview extracts will be carefully selected and embedded in the narrative to provide compelling evidence.

For the survey data, we will use descriptive statistics and correlational analysis to explore the relationships between participants' views, perceptions, knowledge and aspirations. This analysis will evolve as informed by the results of the qualitative phase. In the final analysis, findings from qualitative and quantitative data analyses will be integrated. Utilisation of Situational Analysis requires quantitative data describing the studied population to effectively situate qualitative data within the social structures present. We will adopt the convergent design joint displays to present both data using statistics-by-themes and side-by-side comparisons (Guetterman et al., 2015). We will use our theoretical framework to draw meta-inferences from joint displays, which will inform our actions or recommendations, along with all other technical data, to develop the site-specific rehabilitation system.

Rigour

Each researcher will maintain a field note and reflexive journal to identify the development of codes and to document their experience (Nowell et al., 2017). We will independently code the data, compare our coding and reflections, and discuss competing views to ensure credibility (Lincoln & Guba, 1985). We will use detailed descriptions of our methodology, data and results to show that our research findings can be applied to other legacy mine contexts. Member-checking will be done for interview transcripts. The community validation process required by the NCIP will also ensure that our results accurately represent the community's views, beliefs, perceptions, aspirations and knowledge.

Declaration of Conflicting Interests

The author(s) declared no potential conflicts of interest with respect to the research, authorship, and/or publication of this article.

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Ethical Approval and Consent

Apart from the Certificate of Preconditioned acquired from the NCIP Regional Office in Benguet, we also applied for institutional ethics. Ethics approval was granted by the University of Mindanao Ethics Review Committee (UMERC-2022-289).

Dissemination and Outcomes

As part of our MOA with the community, we will submit our research findings to the community, NCIP municipal, regional and central offices and the library. In addition, we plan to disseminate our results in conferences, symposia, peer-reviewed journals, and media releases. Further, we will also submit our research reports to the funding agency.

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Supplemental Material

Supplemental Material for this article available online.

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