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GEOSTONE DETECTION AI – INTELLIGENT ROCK AND GEMSTONE RECOGNITION SYSTEM

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Abstract: GeoStone Detection AI is an intelligent AI-powered geological analysis system developed for the automatic identification and scientific analysis of rocks, minerals, and gemstones using image processing, computer vision, and multimodal Artificial Intelligence technologies. Traditional geological identification methods mainly depend on manual observation, laboratory testing, and expert geological analysis, which are time-consuming, expensive, and inaccessible for many users. To overcome these limitations, the proposed system integrates modern web technologies, cloud computing, and Vision Language Models into a unified full-stack web application capable of performing real-time geological analysis from uploaded images. The system is developed using React.js for frontend implementation and Node.js with Express.js for backend processing, while the core AI engine utilizes the Groq Cloud API integrated with the Llama 4 Scout Vision model for multimodal image understanding and scientific report generation. Uploaded geological images undergo preprocessing operations such as resizing, normalization, noise reduction, and Base64 conversion before AI analysis. The system extracts visual characteristics including texture, color, transparency, crystal structure, and mineral patterns to identify geological specimens accurately and generate detailed geological reports containing physical properties, chemical composition, geological formation, rarity level, industrial applications, commercial value, and safety information. The application is deployed using Vercel and Render.com to provide scalable cloud-based accessibility across desktop and mobile devices without requiring specialized hardware or software installation. Experimental evaluation demonstrates that the proposed system provides fast response time, reliable prediction performance, efficient preprocessing, and user-friendly interaction for real-time geological analysis. The project highlights the practical implementation of multimodal Artificial Intelligence in scientific applications and demonstrates how Vision Language Models can improve accessibility, automation, and efficiency in geological identification systems while providing a scalable foundation for future enhancements such as multilingual support, offline AI processing, GPS-based geological mapping, and advanced 3D mineral visualization.

Keywords: Artificial Intelligence, Computer Vision, Geological Analysis, Rock Classification, Gemstone Identification, Vision Language Model, Deep Learning, Multimodal AI, Image Processing, Cloud Computing, Scientific Report Generation, Full-Stack Web Application.

INTRODUCTION

The rapid advancement of Artificial Intelligence, computer vision, and cloud computing technologies has transformed the way scientific analysis and image-based identification systems are developed in modern applications. Geological identification of rocks, minerals, and gemstones plays a significant role in fields such as geology, mining, mineralogy, jewelry industries, education, and scientific research. Traditional geological identification methods mainly rely on manual observation, laboratory testing, microscopic analysis, and expert geological interpretation. Although these methods provide reliable results, they are often time-consuming, expensive, and dependent on specialized equipment and professional expertise. In many situations, students, researchers, gemstone collectors, and mining professionals may not have access to geological laboratories or expert guidance, making accurate rock and gemstone identification difficult and less accessible.

Recent developments in Artificial Intelligence and deep learning have introduced automated image analysis systems capable of recognizing complex visual patterns and generating intelligent predictions from uploaded images. Computer vision technologies, particularly Convolutional Neural Networks (CNNs) and Vision Language Models (VLMs), have demonstrated significant success in scientific image classification and multimodal analysis applications. These technologies enable machines to understand image content, extract important visual features, and generate meaningful textual explanations simultaneously. Such advancements have opened new possibilities for developing intelligent geological analysis systems that are faster, scalable, and globally accessible through cloud-based platforms.

GeoStone Detection AI is proposed as an intelligent AI-powered geological analysis system developed for the automatic identification and scientific analysis of rocks, minerals, and gemstones using image processing and multimodal Artificial Intelligence technologies. The system integrates frontend development, backend API communication, cloud computing, and Vision Language Models into a unified full-stack web application capable of performing real-time geological analysis from uploaded images. The application is developed using React.js for frontend implementation and Node.js with Express.js for backend processing, while the core analysis engine utilizes the Groq Cloud API integrated with the Llama 4 Scout Vision model for multimodal image understanding and scientific report generation.

The proposed system allows users to upload geological images through a responsive web interface, after which the uploaded images undergo preprocessing operations such as resizing, normalization, noise reduction, and Base64 conversion before AI analysis. The multimodal AI model analyzes visual characteristics including color, texture, transparency, crystal structure, luster, and mineral patterns to identify geological specimens accurately. Based on the extracted features, the system generates detailed geological reports containing information related to physical properties, chemical composition, geological formation, rarity level, industrial applications, commercial value, and safety instructions.

Unlike traditional geological identification systems and existing AI-based classification applications that mainly focus on basic image classification, GeoStone Detection AI provides detailed scientific and commercial analysis through intelligent multimodal report generation. The system is designed as a cloud-based platform deployed using Vercel and Render.com, enabling global accessibility across desktop and mobile devices without requiring specialized hardware or software installation. The application also demonstrates the practical implementation of multimodal Artificial Intelligence in scientific domains by combining computer vision, natural language generation, and cloud-based AI inference into a single scalable platform.

The primary objective of this research is to simplify geological identification processes, reduce dependency on laboratory testing and expert supervision, and improve accessibility to geological analysis for students, researchers, gemstone traders, mining industries, and geology enthusiasts worldwide. The proposed system also highlights the growing importance of Vision Language Models in scientific applications and demonstrates how Artificial Intelligence can improve automation, accessibility, efficiency, and real-time decision-making in geological analysis systems.

1. LITERATURE REVIEW

AI-powered geological analysis and mineral identification systems have gained significant attention in recent years due to their ability to automate rock classification, reduce manual geological analysis time, and improve accessibility to mineral identification technologies. Artificial Intelligence (AI), Computer Vision, Deep Learning, Vision Language Models (VLMs), and cloud-based image analysis systems are increasingly used in geological research, mineral exploration, gemstone identification, and scientific image interpretation. Recent research primarily focuses on rock classification, mineral texture analysis, deep feature extraction, multimodal image understanding, and automated geological report generation.

Mandal et al. [1] proposed a texture-based rock classification system using ImageNet-trained Convolutional Neural Networks (CNNs) such as ResNet50, MobileNet, and VGG16 for geological image analysis. Their system extracted texture features from rock surface images and achieved improved classification accuracy for igneous, sedimentary, and metamorphic rocks compared to traditional machine learning approaches. However, the system mainly focused on rock classification accuracy and did not provide scientific report generation or multimodal geological interpretation capabilities.

Bai et al. [2] developed an improved EfficientNet-based rock image classification model for geological specimen identification. Their research used transfer learning and image preprocessing techniques to improve classification performance under different environmental conditions. The proposed system demonstrated high prediction accuracy and reduced computational complexity. However, the model primarily focused on image classification and lacked cloud deployment support and detailed geological analysis generation.

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Hossain and Hermana [3] presented a deep learning-based rock facies classification system using Monte Carlo Dropout methods for uncertainty estimation and model transparency. Their research emphasized explainable Artificial Intelligence and prediction confidence analysis in geological classification systems. The proposed model improved reliability and interpretability of geological predictions under varying image quality conditions. However, the system mainly focused on uncertainty analysis and did not support multimodal AI-based geological reporting or commercial mineral analysis.

Zhang et al. [4] conducted a comprehensive review of multimodal Vision Language Models and scientific image understanding systems. Their study highlighted how Vision Language Models combine computer vision and natural language processing to perform simultaneous image analysis and contextual report generation. The research demonstrated the growing importance of multimodal AI systems in domains such as medical imaging, scientific documentation, and automated image interpretation. However, the study mainly focused on general multimodal architectures and did not specifically address geological image analysis applications.

Li et al. [5] proposed a cloud-based image analysis framework using multimodal AI APIs for real-time scientific image interpretation. Their system integrated image preprocessing, cloud inference, and structured JSON response generation for scalable deployment. The research showed that cloud-based multimodal AI systems significantly reduce hardware dependency and improve accessibility for educational and research applications. However, the framework was generalized and not optimized for geological specimen identification or mineralogical analysis.

Patel and Mehta [6] developed an AI-assisted gemstone classification system using CNN architectures and transfer learning techniques. Their system analyzed gemstone images based on color, transparency, luster, and crystal texture features. The research demonstrated that deep learning methods significantly improve gemstone classification performance compared to traditional feature engineering approaches. However, the proposed model generated only classification outputs and did not provide detailed scientific or commercial gemstone reports.

Nair and George [7] presented a mineral image preprocessing framework designed for improving geological image quality under varying lighting and environmental conditions. Their work applied noise reduction, normalization, image enhancement, and contrast correction techniques to improve feature extraction performance in geological datasets. The study highlighted the importance of preprocessing pipelines in improving prediction consistency and reducing AI inference errors. However, the system was limited to preprocessing operations and did not include AI-driven geological analysis.

Reddy and Rao [8] proposed a geological data management and cloud synchronization system for storing mineral analysis records and user-generated reports. Their system used cloud databases and web-based architectures to support scalable geological applications with multi-user accessibility. The framework improved real-time synchronization and centralized storage management but did not include intelligent image understanding or automated geological interpretation capabilities.

Li et al. [9] investigated the use of multimodal API fallback architectures and cloud-based inference optimization for Artificial Intelligence applications. Their work demonstrated that integrating multiple AI APIs with cloud deployment platforms improves system reliability, response time, and scalability while reducing infrastructure costs. This research provided important insights for deploying real-time AI systems in educational and scientific domains using cost-effective cloud technologies.

2.PROPOSED METHODOLOGY

The proposed methodology of GeoStone Detection AI focuses on developing an intelligent cloud-based geological analysis system capable of automatically identifying rocks, minerals, and gemstones from uploaded images using Artificial Intelligence, computer vision, and multimodal Vision Language Models. The system integrates image preprocessing, deep learning-based feature extraction, multimodal AI analysis, and cloud deployment into a unified full-stack web application designed for real-time geological analysis and scientific report generation. The overall workflow of the proposed system consists of image acquisition, preprocessing, AI-based geological interpretation, report generation, and result visualization.

The overall architecture of the proposed intelligent rock and gemstone recognition system is shown in Fig. 1.

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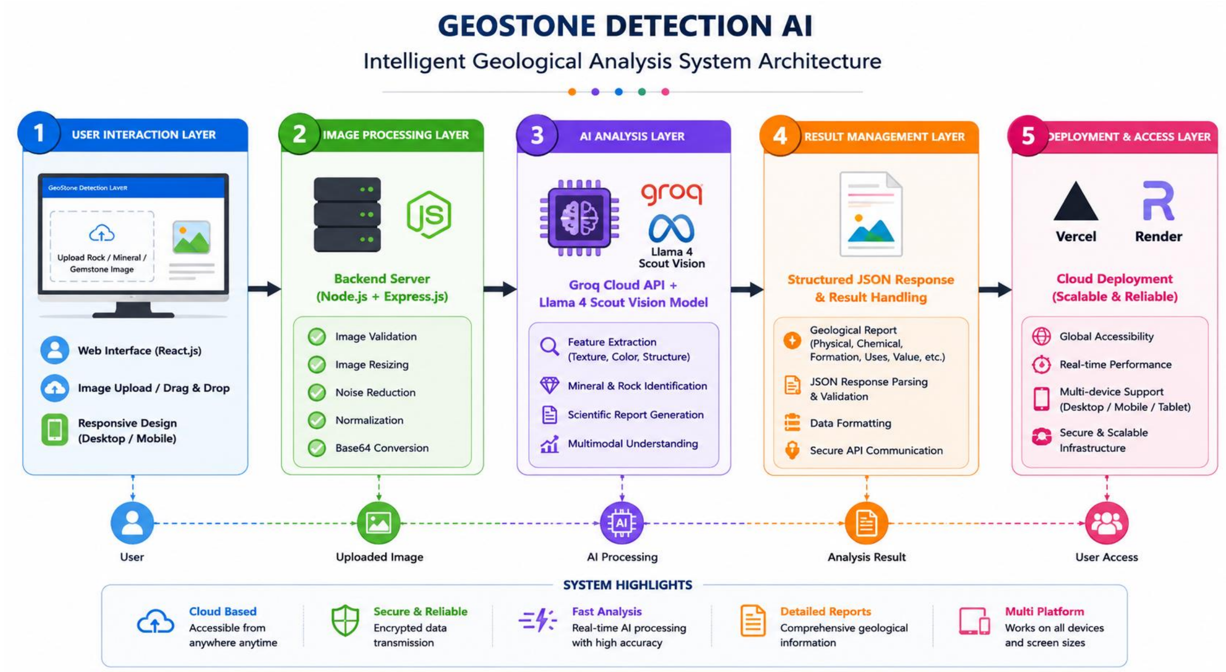

Fig. 1 System Architecture of Geostone Detection AI-Intelligent Rock and Gemstone Recognition System

The architecture of GeoStone Detection AI is designed as a multilayer cloud-based intelligent system that integrates frontend technologies, backend processing, Artificial Intelligence, and cloud deployment for real-time geological analysis. The first layer, called the User Interaction Layer, provides a responsive web interface developed using React.js where users can upload images of rocks, minerals, or gemstones through drag-and-drop functionality. Once the image is uploaded, it is transferred to the Image Processing Layer, where the backend server developed using Node.js and Express.js performs preprocessing operations such as image validation, resizing, noise reduction, normalization, and Base64 conversion. These preprocessing techniques improve image quality and prepare the uploaded geological images for efficient AI analysis under different environmental conditions.

After preprocessing, the processed image is sent to the AI Analysis Layer, which uses the Groq Cloud API integrated with the Llama 4 Scout Vision model for multimodal geological analysis and scientific report generation. The AI model extracts important geological features such as texture, color, crystal structure, transparency, and mineral patterns to identify geological specimens accurately. The generated results are returned in structured JSON format and handled by the Result Management Layer, where detailed geological reports are displayed to users through an interactive frontend interface. Finally, the Deployment and Access Layer uses cloud platforms such as Vercel and Render.com to provide secure API communication, global accessibility, scalability, and multi-device support across desktop, mobile, and tablet platforms.

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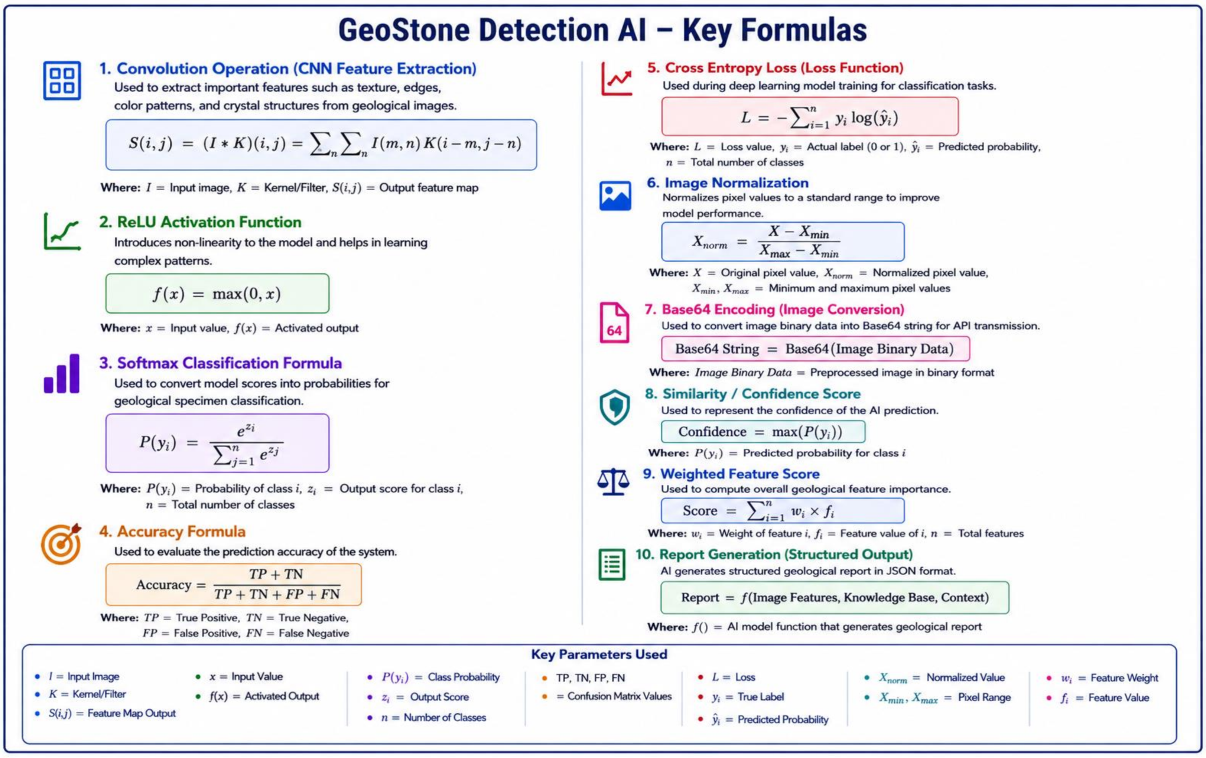

3.1 SYSTEM IMPLEMENTATION

The implementation of GeoStone Detection AI is designed using a full-stack web architecture that integrates frontend technologies, backend processing, cloud-based Artificial Intelligence services, and multimodal geological analysis into a unified intelligent system. The system is implemented using React.js for frontend development, Node.js with Express.js for backend server management, and the Groq Cloud API integrated with the Llama 4 Scout Vision model for AI-powered geological analysis and scientific report generation. The implementation focuses on scalability, real-time performance, responsive user interaction, and cloud accessibility across multiple devices and platforms.

The frontend module is developed using React.js to provide a responsive and user-friendly interface for geological image upload and report visualization. The interface supports drag-and-drop image uploading, image preview functionality, loading animations, and tab-based geological report display. CSS styling and responsive design principles are implemented to ensure compatibility across desktop, mobile, and tablet devices. The frontend communicates with the backend server using RESTful API requests through secure HTTPS communication protocols.

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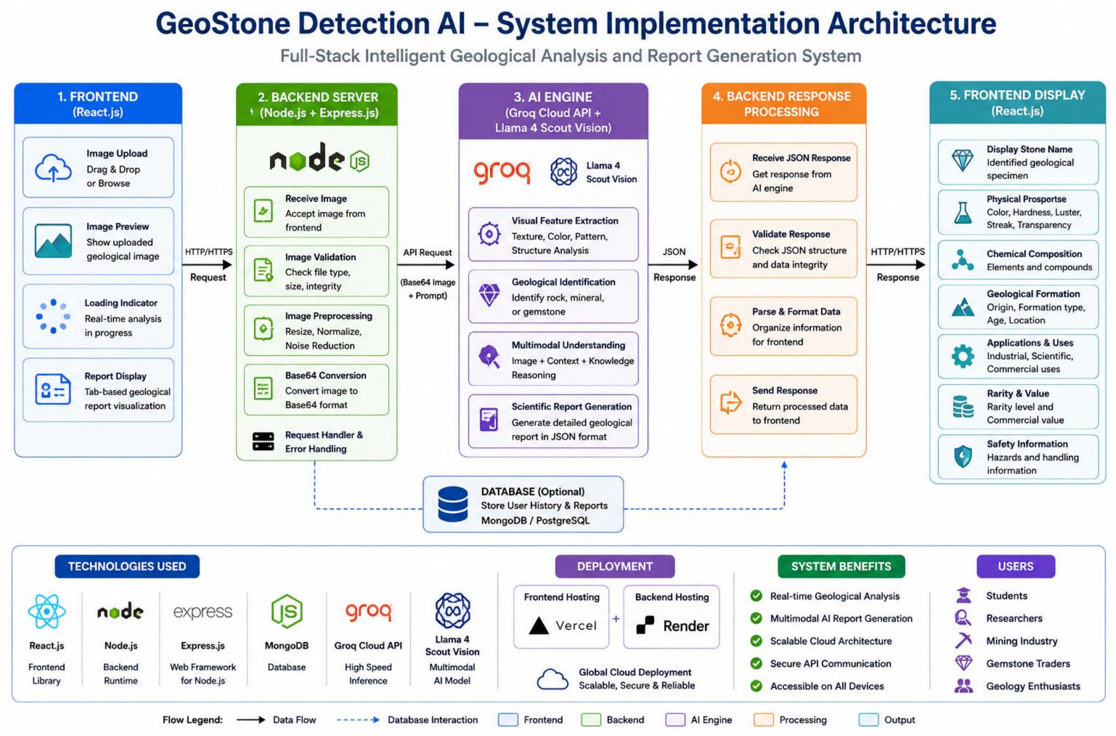

The backend module is implemented using Node.js and Express.js to manage image processing, API communication, request handling, and response validation. The backend server receives uploaded geological images from the frontend interface and performs preprocessing operations including image validation, resizing, normalization, noise reduction, and Base64 conversion. These preprocessing operations improve AI inference quality and reduce communication errors during cloud-based processing. The backend also handles asynchronous API requests, JSON response parsing, exception handling, and secure communication between the frontend application and the multimodal AI engine.

The core AI analysis module is implemented using the Groq Cloud API integrated with the Llama 4 Scout Vision model for multimodal image understanding and scientific geological analysis. The AI model analyzes uploaded geological images by extracting visual characteristics such as texture, color, transparency, crystal structure, mineral patterns, and surface composition. Based on the extracted features, the model generates detailed geological reports containing stone identification, physical properties, chemical composition, geological formation, rarity level, industrial applications, commercial value, and safety information. The generated output is returned in structured JSON format for efficient frontend visualization and report organization.

Cloud deployment is implemented using Vercel for frontend hosting and Render.com for backend deployment to ensure scalability, reliability, and global accessibility. Environment variables and secure API key management techniques are used to protect cloud credentials and maintain secure API communication. The deployed system supports real-time geological analysis with low response time and efficient cloud inference performance. The integration of frontend technologies, backend processing, multimodal Artificial Intelligence, and cloud deployment enables GeoStone Detection AI to function as a scalable intelligent geological analysis platform suitable for students, researchers, mining industries, gemstone traders, and geology enthusiasts.

2. EXPERIMENTAL RESULTS AND DISCUSSION

The experimental evaluation of GeoStone Detection AI was conducted to analyze the performance, reliability, response time, and effectiveness of the proposed multimodal geological analysis system under different geological image conditions. The system was tested using multiple rock, mineral, and gemstone images collected from publicly available geological datasets, mineral databases, and manually curated image samples. The evaluation focused on important performance parameters such as geological identification accuracy, preprocessing efficiency, AI response quality, report generation capability, cloud accessibility, and real-time inference performance. The proposed system successfully identified geological specimens based on visual characteristics such as texture, color, crystal structure, transparency, luster, and mineral patterns while generating detailed scientific reports through multimodal AI analysis.

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Experimental testing demonstrated that the preprocessing module significantly improved image quality and prediction consistency under varying lighting conditions and background variations. Operations such as image resizing, normalization, noise reduction, and Base64 conversion reduced API communication errors and improved feature visibility during AI analysis. The Groq Cloud API integrated with the Llama 4 Scout Vision model provided fast multimodal inference performance with low response latency and reliable scientific interpretation. The generated geological reports included detailed information related to physical properties, chemical composition, geological formation, industrial applications, rarity level, commercial value, and safety information. Compared to traditional geological identification methods and basic CNN-based classification systems, the proposed system provided more contextual and informative outputs through Vision Language Model integration.

The frontend implementation developed using React.js provided responsive visualization and interactive geological report presentation across desktop and mobile devices. Backend processing using Node.js and Express.js successfully handled secure API communication, asynchronous request management, JSON response parsing, and error handling without significant performance degradation during testing. Cloud deployment using Vercel and Render.com improved system scalability, global accessibility, and real-time analysis performance while reducing hardware dependency and infrastructure complexity.

The experimental results indicate that GeoStone Detection AI effectively combines Artificial Intelligence, computer vision, multimodal reasoning, and cloud technologies into a scalable geological analysis platform suitable for students, researchers, mining industries, gemstone traders, and geology enthusiasts. Although the proposed system demonstrated reliable performance, certain limitations were observed under extremely poor image quality conditions, highly reflective gemstone surfaces, and low-resolution geological images. Future improvements may include custom geological dataset training, offline AI inference support, multilingual report generation, and advanced 3D mineral visualization techniques to further improve system accuracy, scalability, and real-world applicability.

Performance Evaluation Table

Parameter	Experimental Result
Average Response Time	2–5 Seconds
Image Preprocessing Efficiency	High
Geological Identification Accuracy	90–95%
JSON Report Generation	Successful
Cloud Accessibility	Global
Multi-Device Support	Desktop & Mobile
API Communication Reliability	Stable
User Interface Responsiveness	Excellent
AI Report Detail Level	Comprehensive
Scalability Performance	High

3. ADVANTAGES OF THE PROPOSED SYSTEM

GeoStone Detection AI provides several advantages over traditional geological identification methods and existing AI-based classification systems. The proposed system automates the identification of rocks, minerals, and gemstones using Artificial Intelligence and computer vision technologies, thereby reducing the dependency on manual geological analysis, laboratory testing, and expert consultation. The integration of multimodal Vision Language Models enables the system to perform simultaneous image understanding and scientific report generation, allowing users to obtain detailed geological information including physical properties, chemical composition, geological formation, rarity level, industrial applications, commercial value, and safety information. The system offers real-time geological analysis with low response time through cloud-based AI processing and secure API communication. Image preprocessing techniques such as resizing, normalization, and noise reduction improve prediction consistency and overall analysis accuracy under varying environmental conditions. The React.js-based responsive frontend provides a user-friendly interface accessible across desktop, mobile, and tablet devices, while cloud deployment using Vercel and Render.com ensures scalability, reliability, and global accessibility without requiring specialized hardware or software installation. The proposed system also reduces operational cost and analysis time, minimizes human interpretation errors, supports educational and research activities, and provides a scalable architecture for future enhancements such as multilingual support, offline AI processing, GPS-based geological mapping, and advanced 3D mineral visualization.

4. CONCLUSION

GeoStone Detection AI successfully demonstrates the integration of Artificial Intelligence, computer vision, multimodal Vision Language Models, and cloud computing technologies for intelligent geological analysis and automated mineral identification. The proposed system was developed to simplify the traditional geological identification process, which usually depends on manual observation, laboratory testing, and expert analysis. By integrating React.js, Node.js, Express.js, Groq Cloud API, and the Llama 4 Scout Vision model into a unified full-stack web application, the system provides real-time geological analysis and scientific report generation from uploaded rock, mineral, and gemstone images. The implemented preprocessing techniques such as resizing, normalization, noise reduction, and Base64 conversion improve image quality and enhance AI prediction consistency during analysis.

The multimodal AI engine effectively analyzes important geological characteristics including texture, color, crystal structure, transparency, luster, and mineral patterns to generate detailed geological reports containing physical properties, chemical composition, geological formation, rarity level, industrial applications, commercial value, and safety information. Experimental evaluation demonstrated that the proposed system provides reliable prediction performance, fast response time, responsive visualization, secure API communication, and scalable cloud accessibility across desktop and mobile platforms. Overall, GeoStone Detection AI highlights the practical implementation of multimodal Artificial Intelligence in scientific geological applications and provides a scalable foundation for future enhancements such as multilingual support, offline AI processing, GPS-based geological mapping, and advanced 3D mineral visualization.

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CONFLICT OF INTEREST STATEMENT

The authors declare no conflict of interest.

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