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First Hydrothermal Vent Communities from the Indian Ocean Discovered

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ABSTRACT—Thriving chemosynthetic communities were located for the first time in the Indian Ocean between 2420 and 2450 m, on a volcanic knoll at the eastern crest of an axial valley, approximately 22 km north of the Rodriguez Triple Junction. The communities were distributed in a 40m by 80m field around the knoll. At least seven active vent sites, including black smoker complexes that were emitting superheated water at 360°C, were observed at the field. The faunal composition of the Indian Ocean hydrothermal vent communities had links to both Pacific and Atlantic vent assemblages. This discovery supports the hypothesis that there is significant communication between vent faunas in the Pacific and Atlantic Oceans via active ridges in the Indian Ocean.

INTRODUCTION

The discovery of deep-sea chemosynthetic communities associated with thermally active spreading centers has had a major impact on ocean sciences in the latter half of the twentieth century. Exploration of these communities using submersibles has revealed not only completely new forms of life, but also had implications reaching far beyond a new understanding of the diversity of life in the deep oceans. As yet, even a fundamental understanding of the prevalence of hydrothermal vent communities, or the biogeographical patterns and life histories of vent fauna remains far from complete. One hypothesis explaining the biogeography of vent faunas on a global scale states that chemosynthetic communities have dispersed along active hydrothermal systems in a "stepping stone" linking the world's oceans (Tunnicliffe and Fowler 1996; Tunnicliffe *et al*. 1998). Many such communities have been reported along active margins in the Atlantic Ocean (Van Dover 1995; Gebruk *et al*. 1997) and Pacific Ocean (Hessler and Lonsdale 1991; Tunnicliffe 1991; Lutz and Kennish 1993; Desbruyéres *et al*. 1994; Hashimoto *et al*. 1995), but none to date had been discovered in the Indian Ocean. Accordingly, oceanographers have been searching for hydrothermal communities in the Indian Ocean to gain a fuller understanding of the biogeography of chemosynthetic faunas. Evidence suggesting their presence in the Indian Ocean has been reported previously without directly detecting any vent sites (e.g., detection of hydrothermal plumes (Herzig and Plüger 1988; German *et al*. 1998), sampling of vent organisms (Southward *et al*. 1997), and sampling of sulfides (Münch *et al*. 1999)).

A research cruise was planned by the Japan Marine Sci-

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ence and Technology Center (JAMSTEC) in order to search for hydrothermalism and associated biological communities in the Indian Ocean. The survey area was selected because hydrothermal plumes with CH_4, Mn, Fe and light transmission anomalies were observed during previous cruises by the Research Vessel (R/V) *Hakuho Maru* as well as dives of the manned submersible *Shinkai 6500* (Gamo *et al.* 1996; Fujimoto *et al.* 1999). The first chemosynthetic communities in the Indian Ocean were discovered during the cruise. Preliminary analyses show that the faunal composition of the Indian Ocean communities is intermediate between some Atlantic and Pacific communities. These observations provide the first direct evidence supporting the global dispersal of common chemosynthetic genera via the active spreading ridges of the Indian Ocean.

MATERIALS AND METHODS

In August 2000, a research cruise using the Remotely Operated Vehicle (ROV) *Kaiko* and its support ship, the R/V *Kairei*, was conducted along the northern extremity of the first segment of the Central Indian Ridge, approximately 22 km north of the Rodriguez Triple Junction (Fig. 1). Surveys focused on a small volcanic knoll (named the Hakuho Knoll; Fig.1). Prior to the ROV dives, topographic surveys using a SeaBeam 2100 on the R/V *Kairei*, tow-yo observations using a CTD and transmissiometer and biological and geological observations using a deep tow TV camera system were conducted as site surveys. After the site surveys, four dives were made using the ROV *Kaiko* along the western slope of the knoll.

During the dives, vent organisms were collected using a suction sampler (Hashimoto *et al*., 1992). The preliminary faunal list was made out based on the collected biological samples and the video records. The *in situ* temperature of the vent fluids and pH value of the sampled vent fluids were measured using a self-recorded thermometer (Rigo-Sha Co. Ltd., RMT-0-400) and a pH meter (Metrohm Co. Ltd., Model-1654), respectively.

The similarity at the familial level between the Indian Ocean vent fauna and the other vent faunas (Tunnicliffe *et al*., 1998; Hashimoto *et al*., 1995; Hessler and Lonsdale, 1991; Hashimoto *et al*., 1999; Desbruyéres *et al*., 1994) was examined using the coefficient of community (Jaccard, 1902).

RESULTS AND DISCUSSION

During the site surveys, evidence suggesting hydrothermalism including light transmission anomalies, discolored

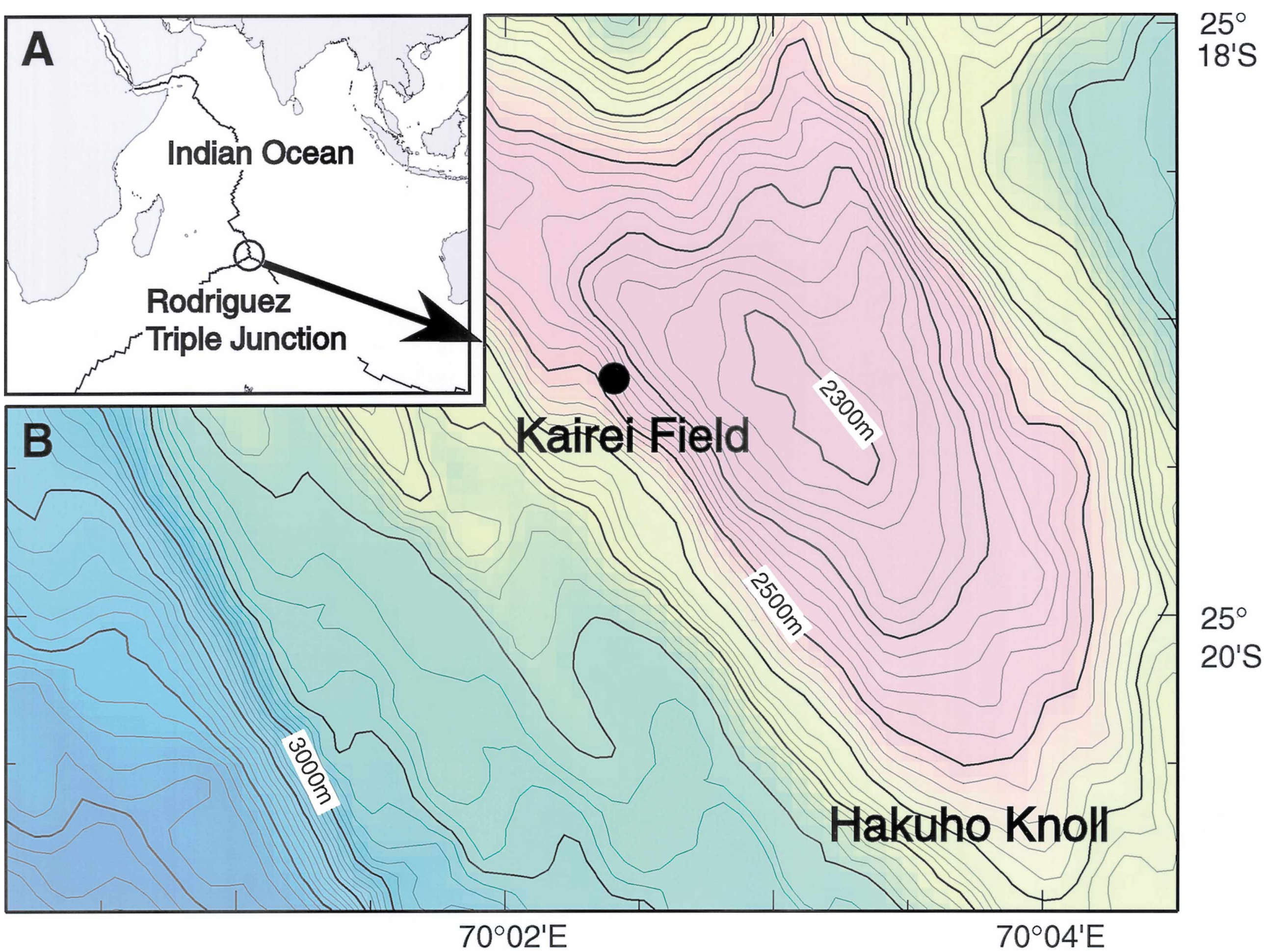

Fig. 1. (A) Map showing the Rodriguez Triple Junction (open circle). (B) Bathymetric map (20 m contours) of the Hakuho Knoll located north of the Rodriguez Triple Junction in the Indian Ocean. Solid circle indicates the active hydrothermal field named the Kairei Field (25°19.17'S, 70°02.40'E).

areas, dead vesicomyid clams and aggregations of actinians were observed along the western slope of the Hakuho Knoll. On August 25, 2000, the *Kaiko* successfully located the first active hydrothermal site in the Indian Ocean. Heated effluent plumes with densely associated biological communities were distributed in a 40 m by 80 m field around the knoll between depths of 2420 m and 2450 m (25°19.17'S, 70°02.40'E). This area was named the Kairei Field. We observed at least seven active vent sites including black smoker complexes, the largest of which was over 10 m in height. The maximum temperature measured from an active black smoker (Fig. 2) was 360°C and the pH (at 25°C) was 3.4.

Communities were dominated by swarms of densely packed shrimp belonging to the genus *Rimicaris* and crowded beds of actinians belonging to the family Actinostolidae (Fig. 3). This is similar in appearance to the Atlantic vent sites TAG, Broken Spur, and Snake Pit (Van Dover 1995; Gebruk *et al*. 1997); *Rimicaris* had been previously reported only from the Atlantic Ocean. However, the iphitimidid polychaete, *Ophryotrocha*, the provannid gastropod *Alviniconcha*, the bythograeid crab *Austinograea*, and the scalepellid cirriped *Neolepas*, known previously only from the Pacific Ocean (Tunnicliffe *et al*., 1998; Hessler and Lonsdale, 1991; Desbruyéres *et al*., 1994; Southward *et al*., 1997; Hashimoto *et al*., 1999), were found and captured at the Kairei Field. Shells, but no live individuals, of the vesicomyid clam were also observed close to the Kairei Field. The clams and other vent organisms observed including actinostolid actinians, *Branchipolynoe* polynoids, *Lepetodrilus* limpets, *Phymorhynchus* gastropods, *Bathymodiolus* mussels, *Chorocaris* shrimp and *Munidopsis* galatheids were reported from both Atlantic and Pacific hydrothermal vent sites (Tunnicliffe *et al*., 1998; Gebruk *et al*., 2000). Although our observation time was limited, it is interesting to note that no new families were found. Twenty species of vent-specific organisms were collected within and near the Kairei Field, and additional six species were observed (Table 1).

Although our observations were preliminary, a coefficient of community comparison at the familial level between the hydrothermal vent faunas in the Indian Ocean (Kairei Field) and those in the northeastern, eastern, northwestern and southwestern Pacific and Atlantic Oceans was instructive. Taxa included were limited to: actinians, polychaetes, gastropods, bivalves, cirripeds, shrimps, brachyuran crabs, galatheids, holothurians and fishes observed and/or captured at the Kairei Field. The southwestern and northwestern Pacific both showed a closer affinity to the Indian Ocean site than did the eastern Pacific Ocean or Atlantic Ocean, while the northeastern Pacific sites had a coefficient of community somewhat lower than these groups (see Table 2). This suggests that significant communication exists between the vent fauna in the western Pacific Ocean and the Indian Ocean despite no dis-

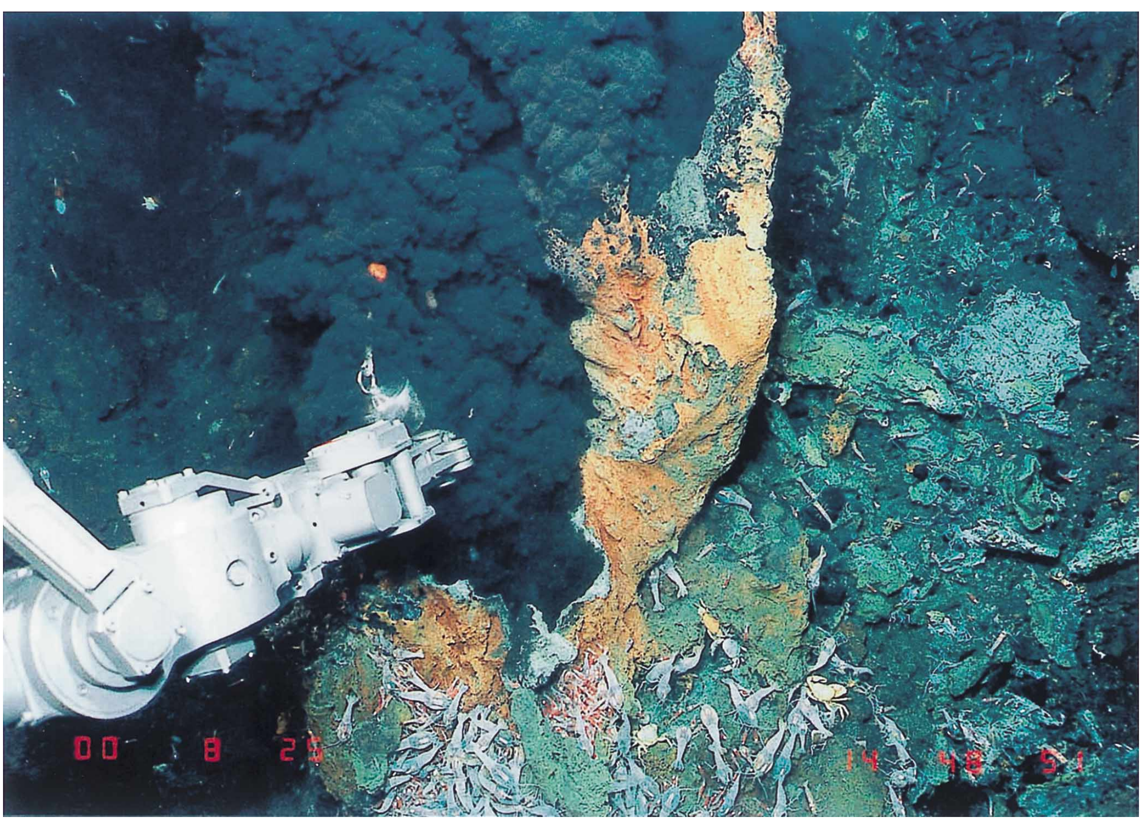

Fig. 2. Measuring the temperature of an active black smoker by the ROV *Kaiko* at the Kairei Field. The temperature of superheated water was 360°C at maximum. *Rimicaris* and *Chorocaris* shrimps and *Austinograea* crabs are aggregated at the base of the black smoker (25°19.17'S, 70°02.37'E, 2450 m).

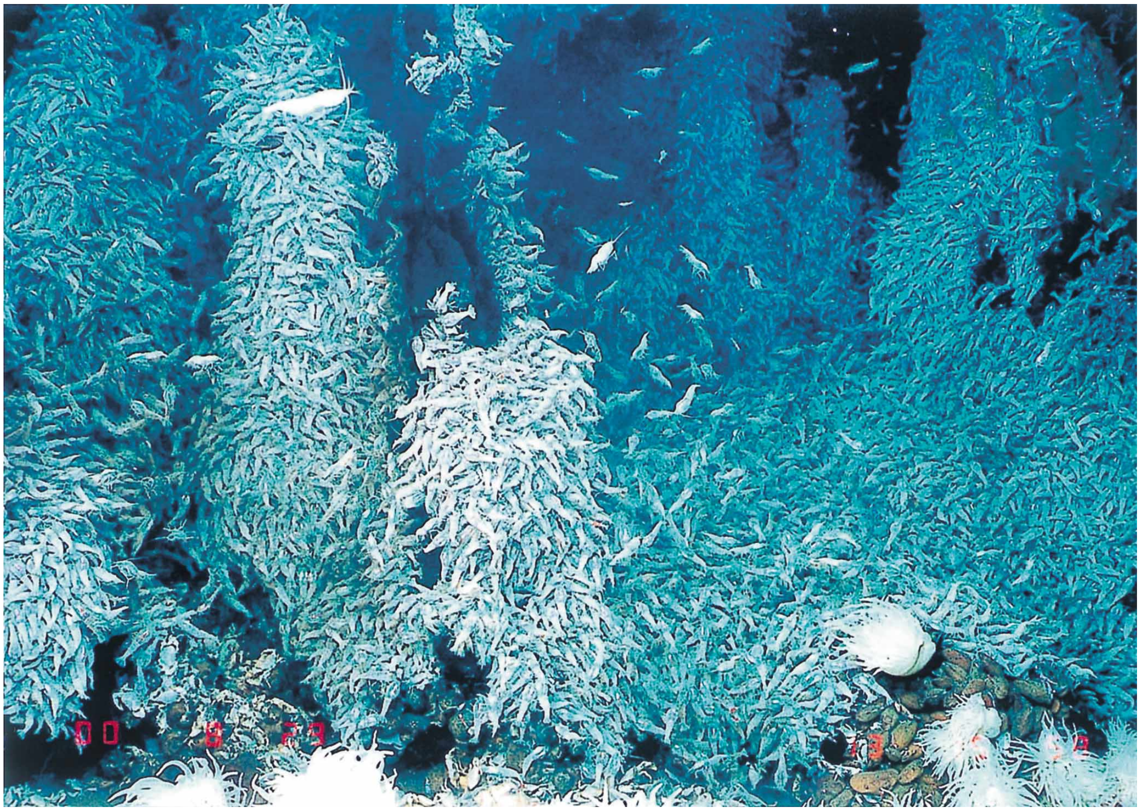

Fig. 3. Typical scene characterized by *Rimicaris* swarms and sea anemone aggregations at the Kairei Field. Living beds of *Bathymodiolus* mussels can be observed in the bottom corners. *Austinograea* crabs are observed along the mussel beds (25°19.16'S, 70°02.34'E, 2436 m).

Table 1. Preliminary faunal list from the Kairei Field

#	Phylum	Class	Order	Fmily	Genus & Species	Remarks*
1	Cnidaria	Anthozoa	Actiniaria	Actinostolidae	gen. sp. 1	C
2					gen. sp. 2	C
3			Ceriantharia	Cerianthidae	gen. sp.	V
4	Annelida	Polychaeta	Eunicida	Iphitimidae	*Ophryotrocha* sp.	C
5			Phyllodocida	Polynoidae	*Branchipolinoe* cf. *symmytilida*	C
6					gen. sp. 1	C
7					gen. sp. 2?	C
8	Molluscs	Gastropoda	Patellogastropoda	Neolepetopsidae	gen. sp.	C
9				Acmaeidae	*Bathyacmaea* sp.	C
10			Vetigastropoda	Lepetodrilidae	*Lepetodrilus* sp.	C
11			Caenogastropoda	Provannidae	*Alviniconcha* sp.	C
12					*Provoanna* sp.	C
13				Turridae	*Phymorynchus* aff. *ovatus*	C
14			Neogastropoda	Cancellariidae	*Admete*. sp.	C
15			———	———	unidentified gastropoda	C
16		Bivalvia	Veneroida	Vesicomyidae	*Calyptogena* sp. (dead shells)	V
17			Mytiloida	Mytilidae	*Bathymodiolus* sp.	C
18	Arthropoda	Crustacea	Cirripedia	Scalpellidae	*Neolepas* sp.	C
19			Decapoda	Alvinocarididae	*Rimicaris* sp.	C
20					*Chorocaris* sp. ?	C
21					gen. sp.	V
22				Galatheidae	*Munidopsis* sp.	V
23				Bythograeidae	*Austinograea* sp.	C
24	Echinodermata	Holothuroidea	Holothuriida	Synaptidae	gen. sp.	V
25	Chordata	Osteichthyes	Anguilliformes	Synaphobranchidae	gen. sp.	V
26			Perciformes	Zoarcidae	gen. sp.	C

* C: collected, V: only video recorded

Table 2. Comparison of the coefficient of community (CC) at the familial level between the Indian Ocean vent fauna and other vent faunae. NEP: northeastern Pacific Ocean; EP: eastern Pacific Ocean; NWP: northwestern Pacific Ocean; SWP: southwestern Pacific Ocean; AO: Atlantic Ocean.

Oceans	NEP	EP	NEP	SWP	AO
Vent Sites	Explorer[1] Juan de Fuca [1] Gorda[1]	Guaymas[1] 21°N/EPR[1] 9–13°N/EPR Galapagos[1] 23–27°N/EPR[1]	Minami-Ensei[2] Mariana[3]	Manus[4] North Fiji[5] Lau[5]	Lucky Strike[1] Broken Spur[1] TAG[1] Snake Plt[1]
CC (Indian Ocean)	0.23	0.29	0.34	0.33	0.29

Sources, Tunnicliffe *et al.*, 1998[1]; Hashimoto *et al.*, 1995[2]; Hessler and Lonsdale, 1991[3]; Hashimoto *et al.*, 1999[4]; Desbruyeres *et al.*, 1994[5]

tinct plate boundary between the back-arc complex to the north of New Zealand and the southeastern Indian Ridge (Tunnicliffe *et al.* 1998). Similar communication also exists between the Indian and Atlantic Oceans via the southwestern Indian Ridge and the south Mid-Atlantic Ridge. These are significant observations as they lend support to the hypothesis that much of the Atlantic fauna is derived from the Pacific by way of the western Pacific and Indian Oceans (Tunnicliffe and Fowler 1996; Tunnicliffe *et al.* 1998). The discovery of active chemosynthetic communities in the Indian Ocean of this study will undoubtedly yield significant advances in our understanding of the global-scale biogeography of vent fauna.

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