Institutional erosion of the Innovative Triadic

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During the last decade, PEMEX the Mexican state-owned petroleum company has extracted an average of 3.3 million barrels of crude per day from the Gulf of Mexico (6th world producer[3]). Half of this volume is exported, 78 % goes to the US[4]. These foreign sales represent 43 % of the government income[5]. The remaining crude is refined to cover domestic consumption of gasoline, jet fuel, diesel, lube oils, waxes, fuel oils, asphalt, and other products from petroleum resid process[6]. Most of the processed fuel oil is used by CFE (the Federal Electricity Commission) the second biggest state owned company in Mexico, to produce roughly 44 % of the country's electricity.[7]

The aim of this essay is to analyze both, the institutions and technological capabilities built by the IMP (Mexican Institute of Petroleum[8]) to generate a key input for fuel production: catalysts for petroleum refining[9].

The three main stages, the IMP has gone through will be analyzed: (i) the creation of technological capabilities and basic institutions, (ii) the integration of the Innovative Triadic, involving PEMEX-Refinación (part of PEMEX in charge of petroleum refining), the IMP and multinational corporations in the catalysts innovation process, (iii) the erosion of the Innovative Triadic without the emergence of an alternative innovative and constructive strategy.

The central argument of this paper can be summarized as follows: the IMP achieved modest success in the endogenous production of catalysts for petroleum

1 UAM-Xochimilco, México.
2 Instituto Mexicano del Petróleo.
3 Anuario Estadístico PEMEX 2006. However, Mexico ranks 5th according to The Energy Information Agency (EIA) Top World Oil Producers. www.eia.doe.gov.
4 www.pemex.com
5 Banco de México, Ingresos Presupuestales del Sector Público. www.banxico.org.mx.
6 Informes Anuales de Pemex.
7 Comisión Federal de Electricidad (CFE), www.cfe.gob.mx.
8 The Instituto Mexicano del Petróleo was created on August 23rd 1965.
9 US Chemical Industry Statistical Handbook, (1996) and The US Chemical Industry Performance and Outlook (1996). In 2001 the catalysts World market reached 10 billion dollars in sales. 22% of them were for the oil industry.

refining, under the influence and detailed guidance of PEMEX from 1976-1998. However, research and development (R&D) activity regarding catalysts, inside the IMP underwent an uncertain transition because PEMEX stopped financing R&D projects in petroleum refining catalyst at the IMP. This took place just after a wave of government policies aimed at promoting trade-openness.

Background

Ever since the 1937-nationalization of the oil industry, PEMEX-Refinación has permanently, and increasingly required a series of catalysts as their key input product for crude refining in order to cover the needs of fuel in the country. This demand has been met in two ways: first, through the acquisition of catalysts from specialized multinational corporations (Engelhart, Grace Davison, UOP, etc.). Then, with the integration of the Innovative Triadic, bringing together the IMP, PEMEX-Refinación, and multinational corporations in a scheme of institutional and production cooperation in the last decades. This second way has implied the creation of technological capabilities, by means of specific R&D projects, in order to endogenize part of the invention-innovation process in catalysts production. The bond between PEMEX-Refinación-IMP has been of major importance. It has brought transference of knowledge and technical information to the production apparatus, research and human capital formation institutions in the universities of the country.

Nonetheless, 1998 brought some important changes between the IMP and PEMEX-Refinación questioning the existence of the Innovative Triadic. A more detailed explanation of these three stages is stated below.

1st Stage (1939-1975): Long learning period

In that first period, PEMEX-Refinación purchased directly from multinational corporations, such as: Shell, Standar Oil, Exxon, etc[10]. This relationship covered, not just demand for catalysts; it spreaded practically over all spheres of the oil industry. It was a period of intensive technical and institutional learning inside a supplier-user sphere (Lundvall, 1992) of catalysts and high-end catalysts experts.[11] Short after, Mexico began to accumulate the basic technical and institutional capabilities to develop a national refining industry.

10 See "Memoria de Labores de PEMEX", various issues from the 1970's.

11 The engineers responsible for PEMEX refinery plants developed their technological capabilities as international suppliers acquiring experience regarding quality, coverage and efficiency in the services. This supplier-user relationship was important because it was one of the building blocks for future development, because it would represent the IMP's first experience in the field of catalysis and because the first R&D team was staffed with PEMEX-Refinación engineers. On top of that, catalyst capabilities were decisively boosted by the development of UNAM's Faculty of Chemistry and others, as well as the formation of post-grade researchers in the field of catalysis in other countries.

2nd Stage (1974-1998): The integration of the Innovative Triadic

The creation of the IMP in 1965 was aimed at having a "technological arm" enabling PEMEX, the State Company to reduce its "technical dependency" on the outside[12]. This conception of the IMP is clearly embodied in the predominant framework of the industrial policy of the period called Import Substitutive Industrialization (ISI) [13].

This aim of this policy was to integrate productive chains in the national industry, to internally produce what was being imported, thus boosting the basis for economic growth at that time: the domestic market. In this vision of political economics, the IMP must be considered a key R&D institution, for the productive integration of the national oil industry, being catalysis its main priority.

It was in 1974, when the IMP met fellow researchers from the country's universities and engineers, with practical experience in Mexican refinery plants, to launch its first R&D project in hydrodesulphurization catalysts[14].

A recount of the difficulties from the foundation of the first technological capabilities in the field of catalysis can be read in Aboites et al. (2004). This book refers to difficulties in the IMP being: financial, in human capital (laboratory technician, research scientists, etc.), or in material conditions (labs, pilot plants, etc.), the institutional environment, as well as the uncertainty and setbacks experienced when the first R&D activities in catalysis were conducted and oriented. This shows how complex it was to organize R&D, and build the technological and institutional capabilities.

The "Area of Catalysis"[15] was consolidated slowly, aligning its R&D programs to the PEMEX-Refinación requirements. In 1976, the IMP designed the first catalyst PEMEX was willing to introduce in its refineries. In other words, to be launched in the Mexican refinery market. A production agreement was established with the American multinational UOP, to produce catalysts designed through R&D inside the IMP and contracted by PEMEX-Refinación. This was because no company, in the country's chemical industry, counted on the appropriate capability and technical knowledge. This agreement was signed by PEMEX-Refinación, the IMP, and the multinational corporations thus establishing the basic institutional and technological structure of the Innovative Triadic, in the production of catalysts. One key factor in doing so was that PEMEX-Refinación allowed Industrial Demonstrations to

12 See "Diario Oficial" where the reasons and motives for the creation of the IMP and its relationship with PEMEX are detailed. Secretaría de Gobernación, August 26, 1965. "Decreto que Crea el Instituto Mexicano del Petróleo como Organismo Descentralizado", Mexico, pp. 2-4.

13 Hirschman (1996) explains how the objective of the government policy was to create Productive Bondings during the stage of Import Substitutive Industrialization.

14 IMP 1998), *Análisis Retrospectivo y Prospectivo de la línea de negocios de catalizadores,* IMP. Mexico.

15 Research team with qualifications from Mexican and foreign universities dedicated exclusively to R&D. In the mid 1990's this group exceed 150 members. Ibid.

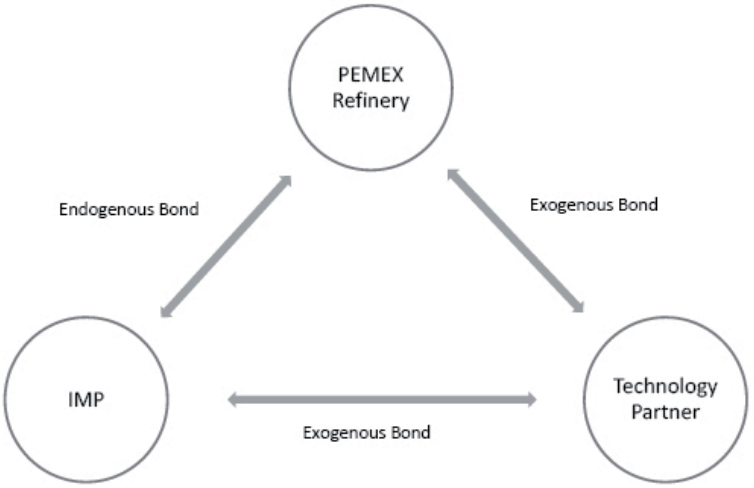
be conducted ex-post during the manufacturing process. This was of paramount importance because Industrial Demonstrations are a sine qua non for the purchase of catalysts in the international markets.

The institutional and technological capabilities of the IMP for the production of catalysts were built along three decades within the Innovative Triadic framework. This was to be the beginning of an endogenization and repositioning of the bond established in the previous stage, when there was a direct relationship between PEMEX-Refinación and the multinational corporations.

Summarizing, the formation and consolidation of the Innovative Triadic is a sui generis institutional and market maze, bringing together three players involved in the innovation process of refining catalysts. These players are (i) PEMEX-Refinación (ii) the IMP, which designs the catalysis, and (iii) multinational corporations (technology partner) who manufacture the catalysts and in turn sell them to PEMEX-Refinación[16]. See Diagram 1.

Under this three-player scheme in the catalyst production, the IMP would introduce 43 catalysts. This meant PEMEX had substantively increased its productivity in refining processes. Chart 1 shows IMP catalysts introduced by PEMEX Refinery through multinational corporations.

Diagram 1: The Innovative Triadic in the IMP (after 1976)



Source : self elaboration

16 Multinational corporations related to the IMP and PEMEX-Refinación are thereafter called Technology Partners. Relationships between the IMP and Technology Partners are established through Technology Transference Agreements (CTT).

Chart 1

No.	Catalyst	Process	Technology Partner	Date for Industrial Demonstration	Expiration
1	IMP-DSD-1(U)	HDS	UOP	1976	1984
2	IMP-DSD-1(K)	HDS	UCI	1979	1995
3	IMP-DSD-2	HDS	Eximgro(MX)	1981	1986
4	IMP-OM-1	Sweetening	Pyosa (MX)	1982	1987
5	IMP-TPC-1	Polymerization	UCI	1983	In use
6	IMP-OM-2	Sweetening	Pyosa (MX)	1983	1987
7	IMP-RNA-1	Naphtha Reforming	Criterion	1983	In use
8	IMP-DSD-3	HDS	Criterion	1984	1988
9	IMP-DSD-5	HDS	UCI	1984	1993
10	IMP-AN-1	Acrylonitrile	UCI	1985	1993
11	IMP-OM-1 (M)	Sweetening	UOP	1985	In use
12	IMP-DSD-4	HDS	Katalco	1986	1989
13	IMP-RNA-2	Naphtha Reforming	Criterion	1986	In use
14	IMP-DZ-1	Acrylonitrile	UCI	1988	1993
15	IMP-DSD-3(+)	HDS	Criterion	1988	In use
16	IMP-DSD-5(E)	HDS	UCI	1988	1996
17	IMP-DSD-5E(+)	HDS	UCI	1989	In use
18	IMP-FCC-06 (R)	FCC	Engelhard	1989	1996
19	IMP-I0-01	FCC Additives	Intercat	1989	1989
20	IMP-I0-02	FCC Additives.	Intercat	1989	1993
21	IMP-FCC-05	FCC	Engelhard	1989	1997
22	IMP-FCC-06	FCC	Engelhard	1990	1996
23	IMP-TPC-1(+)	Polymerization	UCI	1990	1991
24	IMP-DSD-11	HDS	Criterion	1991	In use
25	IMP-I0-03	FCC Additives.	Intercat	1991	1995
26	IMP-DSD-10	HDS	UCI	1993	In use
27	IMP-FCC-05 (MD)	FCC	Engelhard	1993	In use
28	IMP-FCC-05 (R)	FCC	Engelhard	1993	In use
29	IMP-PC-500	FCC Additives.	Intercat	1993	In use
30	IMP-RNA-4	Naphtha Reforming	Criterion	1993	In use
31	IMP-RESOX-01	FCC Additives.	Intercat	1994	Suspended
32	IMP-DSD-1(D)	HDS	UCI	1995	1998
33	IMP-FCC-51	FCC	Grace	1995	In use
34	IMP-I0-04	FCC Additives	Intercat	1995	In use
35	IMP-DSD-14	HDS	Criterion	1996	In use
36	IMP-FCC-11	FCC	Engelhard	1996	In use
37	IMP-FCC-12	FCC	Engelhard	1996	1997
38	IMP-FCC-12 (R)	FCC	Engelhard	1997	In use
39	IMP-OM-4	Sweetening	UOP	1997	In use
40	IMP-RNA-1(M)	Naphtha Reforming	Acreon	1997	In use
41	IMP-DSD-17	HDS	Acreon	1998	In use
42	IMP-FCC-51 (Precision)	FCC	Grace	2000	2000
43	IMP-DSD-14+	HDS	Criterion	2002	In use

Source: Elaboration based on "*Análisis Retrospectivo y Prospectivo de la línea de negocios de catalizadores, IMP*", 1998. Information regarding recent years was supplied by the Gerencia de Soluciones en Catalizadores, IMP.

In an attempt to outperform the Innovative Triadic during the 1978-1981 oil boom two Mexican companies Eximgro[17] and Pyosa[18] covered PEMEX-Refinación demand for catalysts IMP-DSD-2 and IMP-OM-1, respectively. But fluctuant exchange rates in the early 1980's (80 % of raw materials were imported) and a small-size market performed (made) domestic production of catalysts unsustainable.

A new determining factor was added to the catching up process, during the 1990's. Growing legislation against environmental pollution boosted R&D in catalysts. This developed-world phenomenon, which tardily spread over developing nations, had a considerable effect in Mexico[19]. R&D in catalysts was increased as a result of environmental regulation. This issue, named environmental inflexion, has decisively influenced catalyst innovation, as well as the market's dynamism (Challener, 2003).

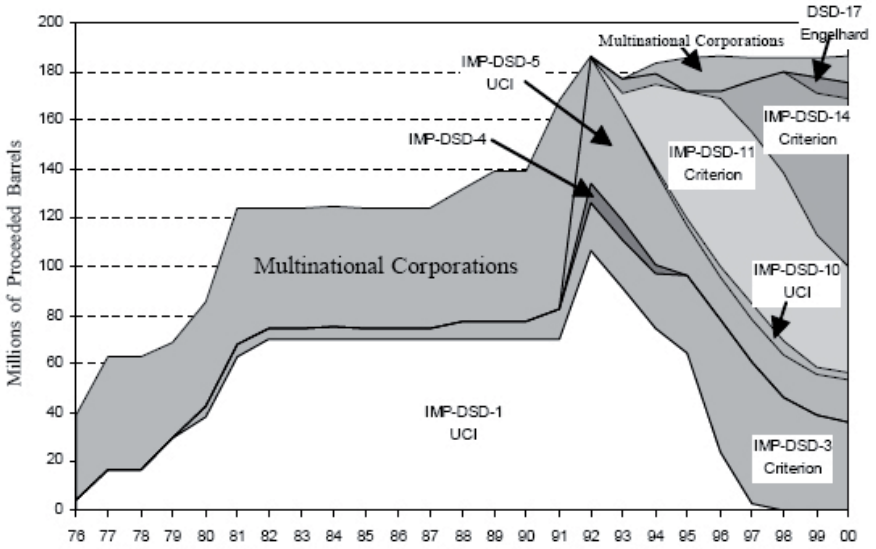
An objective performance indicator of the catalysts produced under the Innovative Triadic scheme is their level of penetration in PEMEX-Refinación. Graphs 1, 2 and 3 illustrate the growing importance of the IMP catalysts inside PEMEX-Refinación. The various catalysts mentioned in Chart 1 are arranged by their type of process. Graph 1 shows Hydrotreating catalysts; Graph 2 shows FCC catalysts and Graph 3 shows Naphtha Reforming catalysts. Presence of Hydrotreating and FCC catalysts is growing whereas in Naphtha Reforming, catalysts grew in 1990 just to fall in 1993. This shows that the level of penetration reached by IMP in PEMEX-Refinación was considerable, given its technical and institutional capabilities.

17 Eximgro S.A. is an agrochemical company specialized in production of solid fertilizers as well as basic formulas and chemicals for industrial use such as monoamonic and diamonic phosphates. It is also an authorized dealer of Rhodia Mexicana, S.A. DE C.V.

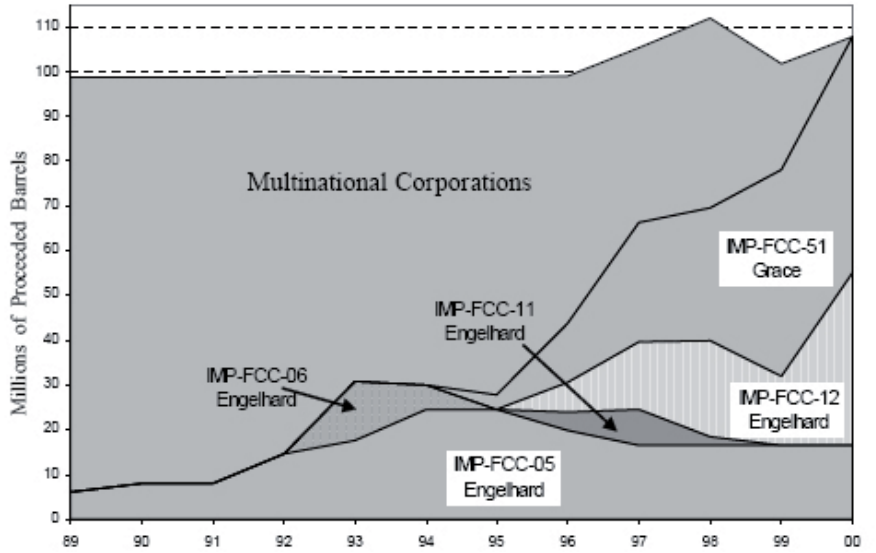
18 Pyosa, S.A. de C.V. is dedicated to production and distribution of fine chemistry products. See: www.pyosa.com .

19 Heredia, (1999), *Evolución de las gasolinas automotrices en PEMEX a partir de la Expropiación Petrolera*. *IMP*, México, Analyses changes in gasoline contents associated with pollution.

Graph 1: Penetration of Hydrotreating catalysts from multinational corporations and IMP, 1976-2000

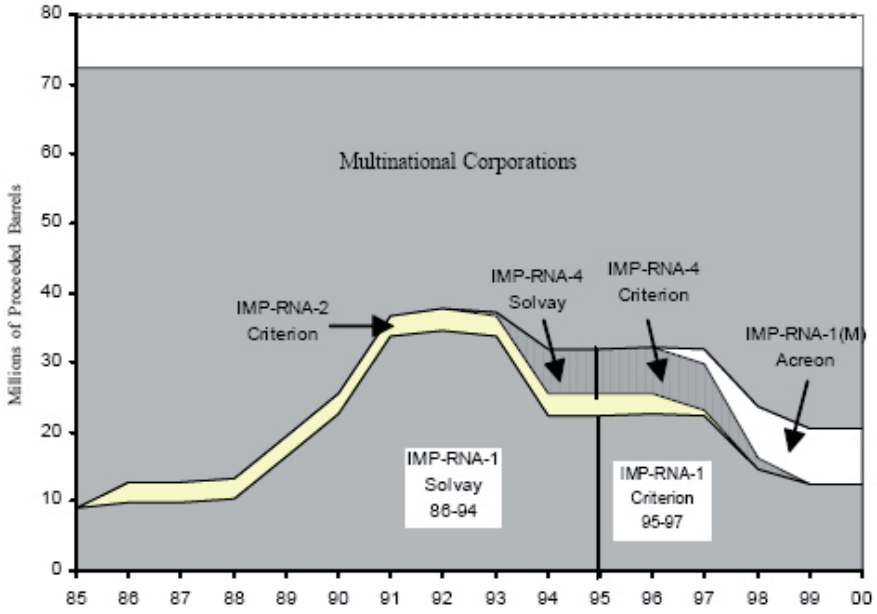


Graph 2: Penetration of FCC catalysts from multinational corporations and IMP 1989-2000



Source of both graphs: Elaboration based on data obtained from Gerencia de Soluciones en Catalizadores IMP, 2002

Graph 3: Penetration of Naphtha Reforming catalysts from multinational corporations and IMP 1985-2000



Source: Elaboration based on data obtained from Gerencia de Soluciones en Catalizadores IMP, 2002

3rd Stage: The erosion of the Innovative Triadic 1998 –present

As a result of trade openness, the NAFTA in 1994, and the nationalization of State Companies like TELMEX or Fertimex the relationship established between the IMP and PEMEX-Refinación, went through an important shift. In effect, in 1998 an institutional inflexion led to the restructuring of the Innovative Triadic. Thus a transition began due to the following institutional and production changes:

The linkage between PEMEX-Refinación and IMP was modified in two outstanding issues: (1) PEMEX-Refinación drastically changed its purchasing terms for catalysts, by making industrial demonstrations mandatory for the new catalysts. This was a setback in their trade tradition. The IMP was unable to comply with such requirement, due to the lack of facilities of industrial scale. (2) PEMEX drastically reduced its financial support to the IMP for its R&D in catalysts, to eventually eliminate it altogether.

As previously explained, this bond between the IMP and PEMEX-Refinación was fundamental in the first stage. It made possible to finance R&D in catalysis and in this way, introduced catalysts to PEMEX-Refinación. As a result, IMP income was notably reduced in the R&D activity in catalysts from 1997 to 2001. Profit margins are a clear example of this: 2.45 m. in 1997 and –114 m. in 2001[20].

Before 1998, the catalyst market in Mexico was dominated by FCC (more than 50 % of the total demand) where IMP catalysts had reached an 80 % penetration. The creation of a huge residual hydrocracking plant (''Miguel Hidalgo'' Refinery in Tula) reduced the proportion of FCC catalyst to 41 % of the total demand. Hence, the IMP saw its market penetration significantly reduced for not counting on this new kind of catalysts[21].

After these changes between the IMP and PEMEX-Refinación, the one only financial source was royalties; agreed on, in previous Contracts of Technology Transference (CTT). This income did not suffice to sustain the level of investment needed in catalyst R&D. For this reason, since then, the IMP catalyst business was no longer sustainable, for it had to supply its own resources derived from remnants in other service areas of the institution.

This situation generated a period of erosion and underutilization of technological capabilities built in previous decades. Besides, other productive sectors in PEMEX not analyzed here, like petrochemistry had stopped to demand polymerization catalysts from the IMP.

In effect, as of 1994 IMP catalysts had been taken out of the petrochemical industry. This way, the second stage of the Innovative Triadic and the royalty model associated to it suffered an institutional inflexion, leading to seek for new opportunities in the catalyst business.

However, there were important changes in the process of institutional changes, which regulate R&D inside the IMP. The following aspects have to be pointed out: (1) the establishment of the Performance Agreement (2000) signed with the Treasury Ministry (SHCP), granting greater freedom to organize and administrate the IMP; (2) the Federal Decree allowing the IMP to market its products (2001), with this bylaw modification the IMP increased its opportunities to reposition itself in the catalysts market[22]; and finally (3) access to federal financing programs from The Ministry of

20 See Chart 4.4.1 in Chapter 4 J. Aboites et al. (2004).
21 Id. at 96.
22 Bylaw modification published on Diario Oficial de la Federación, October 10, 2001.

Energy (SE) and CONACYT (the National Council for Science and Technology) for R&D projects where catalysts could be included.

From mid-2001 and until 2006, the IMP came up with a new strategy to design and market its catalysts. The so-called "Catalysis Group" was created on purpose to explore the R&D and marketing possibilities of its catalysts in its context. This new IMP perspective was focused not only on the domestic market, but also on the possibility to sell its catalysts in international markets, taking advantage of the freedom mentioned above. This opened a new way in the search for a market to the catalysts, which had been monopolized by PEMEX-Refinación under the scheme of the Innovative Triadic.

The IMP achieved considerable success in its attempt to position itself as a specialized supplier of refining catalysts for PEMEX during the 1976-1997 schemes named Innovative Triadic. However, after this stage of success and during the wave of trade-openness policies and the privatization of State Companies R&D activity in catalyst went through an uncertain transition and were not able to determine a consistent strategy for the production and generation of oil refining catalysts.

A disruption between PEMEX-Refinación and the IMP led to an erosion of the Innovative Triadic, and hence significant implications for its technical and institutional capabilities. To analyze the consequences of this erosion, we must look inside the details. When PEMEX looked for technology, refining catalysts, mainly in globalized markets, the IMP lost the bond and objectives that guided its institutional and R&D activities for decades. Institutional changes recently granted, are not enough to establish a strategy based on precise and achievable objectives. This explains why the transition process is so dilated with no encouraging results.

The most important consequence of the erosion of the Innovative Triadic is not the fact that PEMEX has returned to a scheme characterized by purchases of catalysts from the international market under an economic rationale. Rather an underutilization and a steady loss of established technological capabilities (labs, pilot plants) and human resources, established during decades with investment coming from the IMP and PEMEX. ■

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