Executive Summary
Since initial exploration success more than a century ago in onshore California, more than 872 discoveries with total reserves >137 billion barrels oil equivalent (BBOE) have been made in deep-water deposits. A rapid increase in such discoveries began in the 1970s and more than 350 are expected in this decade based on historic trends.

More than 80% of these discoveries are in offshore basins. North America dominates the number of total discoveries as well as reserves but there is an increasing number of African and Brazilian discoveries and fields. Reservoir rocks range in age from Ordovician to Pleistocene. However, more than 90% are in Cretaceous or younger rocks. Passive margins have been the setting for most of these accumulations, and most are in slope depositional environments. However, recent technological advances allowing drilling in deeper waters will lead to more discoveries in lower slope to basin depositional environments. Further statistics on hydrocarbons, reservoir drive, trap types, porosity, and hydrocarbon column heights are discussed from a commercially available database compiled by Cossey and Associates Inc.

Introduction
When many people think “deep-water” oil and gas, they think “current-day offshore waters greater than 183 m (600 ft) or 460 m (1500 ft).” However, not all oil and gas found in deep-water reservoirs is offshore today. A sizable proportion of the reserves in such reservoirs have been found in onshore basins. In fact, the first discoveries in these deposits were discovered onshore in California more than a century ago. Many people also think deep-water reservoirs are “young.” Although most are young “geologically,” the oldest deep-water reservoirs found to date are in Ordovician rocks of onshore Libya, and prolific producers are found in the Pennsylvanian deep-water reservoirs of onshore West Texas.

Geographic, geologic, and other characteristics of fields and discoveries (FADs) in deep-water deposits have been analyzed from published data. Cossey and Associates Inc. has compiled these data during the last eleven years into a searchable, commercially available database. “Discoveries” are defined as oil and gas accumulations that have not been developed or are to be developed (i.e., have not yet been produced). From this published data, 872 FADs have been identified. This estimate of the number of FADs is conservative because some FADs have not been documented, especially as some countries (e.g., Former Soviet Union, China, and others) do not report such data.

Geographic Distribution of Fields and Discoveries
Offshore dominates the global inventory of FADs (Figure 1) because many more offshore basins are present and have been explored. On a continent basis, almost 90% of FADs are in North America, Africa, and Europe (Figure 2). On a country basis, the U.S., U.K., and Brazil contain almost 70% of FADs (Figure 3). However, note that the U.S. has a disproportionate number of FADs.

Historical Summary
The exploration and production (E&P) industry has a long history of exploring and developing deep-water deposits. The earliest discovery was in 1890 at Coalinga Field in the San Joaquin Basin, onshore California (International Petroleum Encyclopedia, 2003). A subsequent discovery was made in the Los Angeles Basin at Whittier in 1896 (Lindblom, 1975). In the early 1900s, discoveries were made in onshore Trinidad at Tabaquite Field (Geological Society of Trinidad and Tobago, 2006) and more discoveries were made in the Los Angeles and Ventura Basins. The first discovery of a deep-water reservoir in the Permian Basin was in 1925 at Wheat Field (Galloway et al., 1983). In the onshore portion of the Gulf of Mexico, deep-water reservoirs were discovered at Buras, Louisiana, in 1939 (Ventress and Smith, 1984) and at Starks, Louisiana, in 1943 in the prolific Hackberry trend (Cossey and Jacobs, 1992). The earliest offshore discovery was in 1951 in Brighton Marine Field, Trinidad (Ablewhite and Higgins, 1968). Figure 4 shows the number of FADs discovered by decade.
A Global Overview of Fields and Discoveries in Deep-water Deposits

**Geographic and Age Distribution of Reserves**

Reserve estimates are available on 688 FADs and total 136.7 BBOE recoverable. Offshore basins dominate this total with 101.4 BBOE (74%). On a continent basis, North America, Africa, and Europe contain 86% of these global reserves (Figure 5). A compilation of reserves by country (those countries with reserves >1.0 BBOE) is shown in Figure 6.

As seen in Figure 7, there are few FADs (only 9%) in reservoirs older than Cretaceous. Miocene reservoirs are found in 15 of the 31 countries in the database and comprise one-quarter of the total number of FADs. More than 50% of the FADs are in young rocks — Miocene and younger. The Oligocene appears to have a very low number of FADs and may be under-explored or has fewer deep-water sediments. A graph of reserves vs. geologic age (Figure 8) shows a very similar distribution to number of FADs vs. geologic age (Figure 7).

![Figure 4](image1.png)

**Figure 4.** Graph of the number of FADs in deep-water deposits versus the decade when discovered. Note the significant and sustained increase starting in the 1970s resulting from E&P efforts in the North Sea and U.S. Gulf of Mexico and later activities in offshore West Africa and Brazil. Data extrapolation suggests the current decade will have >350 FADs, in agreement with the trend starting in the 1970s. N = 746 as 126 FADs (of 872 total) did not have the discovery year noted in published data.

![Figure 5](image2.png)

**Figure 5.** Recoverable reserves (BBOE) by continent.

[See full text for details on geographic and age distribution of reserves, including figures and graphs depicting reserve estimates by country and geologic ages of FADs.]

Viewing the number of FADs and reserves on a percentage basis versus geologic age shows some interesting trends (Table 1). Note that on the basis of reserves versus number of FADs, Pleistocene- and Pliocene-aged reservoirs are under-represented whereas the Miocene, Oligocene, and Eocene Ages are over-represented. Average reserves per FAD show that Oligocene- and Eocene-aged FADs have the highest values.

The largest reserves reported for a discovery or field is for Chicontepec Field(s), onshore Mexico at 12.3 BBOE (Busch, 1992). The largest reported offshore field is Roncador, Brazil, with 3.1 BBOE of recoverable reserves (Rangel et al., 1998). The smallest onshore or offshore FADs are two onshore California fields, Cantua Creek and Horse Meadows, each with estimated reserves of only 200 MBOE (Hall, 1981).

The shallowest FAD is Tabaquite, Trinidad, at 61 m (200 ft) subsea (Ablewhite and Higgins, 1968) and the deepest is the Tahiti discovery (Green Canyon 640), Gulf of Mexico, between 7315 and 8230 m (24,000–27,000 ft) subsea (Yip et al., 2005).
Figure 9. Pie chart of FADs versus depositional setting. Slope deposits are the dominant setting, which also reflects exploration drilling in shallower waters until the 1990s. DW = deep water.

Figure 10. Graph of FADs (N = 820) versus tectonic setting showing that 70% are in passive margin settings, predominantly in the Gulf of Mexico, offshore West Africa, and offshore Brazil.

Figure 11. Graph of hydrocarbon column heights (N = 189). Although 94% are <609 m (2000 ft), some very large columns have been reported.

Figure 12. Data on 126 FADs indicate about half have water-drive reservoirs.

Figure 13. Graph of trap types (N = 387). Data was gathered as “stratigraphic” or “structural.” Thus, “stratigraphic” includes pure stratigraphic trapping and combination structural/stratigraphic trapping. Pure stratigraphic traps are expected to be the smallest group of the three trap types if such data were compiled.
Although published data on reservoir rock thickness and properties are not widely available, a representative chart (N = 291) of porosity is possible (Figure 14). The highest porosity reservoirs (>35%) are shown in Table 2.

### Table 2. Highest porosity deep-water reservoirs.

<table>
<thead>
<tr>
<th>Reservoir</th>
<th>Porosity</th>
<th>Age</th>
</tr>
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<tbody>
<tr>
<td>Red Shank, Main Pass 61, GOM</td>
<td>38%</td>
<td>Pliocene-Plenocene</td>
</tr>
<tr>
<td>Boi, OPL 213, offshore Nigeria</td>
<td>35%</td>
<td>Pliocene-Miocene</td>
</tr>
<tr>
<td>Marquette, Green Canyon 52, GOM (Schneider and Clifton, 1993)</td>
<td>35%</td>
<td>Pliocene</td>
</tr>
<tr>
<td>Harding, CS 923B, U.K. North Sea (McKay et al., 1998)</td>
<td>35%</td>
<td>Tertiary</td>
</tr>
<tr>
<td>Dos Cuadras, onshore California (Goodhue and Carr, 1992)</td>
<td>35%</td>
<td>Pliocene</td>
</tr>
</tbody>
</table>

The highest hydrocarbon pay reported is at the Trident prospect, offshore Gulf of Mexico, with s274 m (900 ft) of oil and gas pay (Blickwede et al., 2004).

Hydrocarbon-type data are available on most FADs. Almost two-thirds of the FADs are oil (Figure 15). Of the oil and condensate reservoirs (excluding gas reservoirs), almost three-fourths have gravities between 20 and 40 degrees API (Figure 16). The lowest reported gravity is at Navarro prospect, Green Canyon 37, Gulf of Mexico at 8.6° API. The highest gravities are reported for condensates of 66° API.

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Conclusions

A significant number of FADs and associated reserves have been found in deep-water deposits. Most are offshore in passive margin settings, FADs have been found in 31 countries and on all continents except Antarctica. However, almost 45% of the reserves are in North America. The U.S. has the most FADs, 466 of 872 globally, and the largest reserves (47 BBOE) due to the many onshore and offshore basins and the long history of, and extensiveness of, E&P activities.

Exploration of deep-water deposits began in onshore California more than a century ago. However, less than 20% of deep-water deposit reserves are onshore. With increased exploration of the U.S. Gulf of Mexico and North Sea beginning in the 1970s and offshore West Africa in the 1990s, an increasing trend of discoveries in deep-water deposits has occurred. We expect more than 350 discoveries in deep-water deposits, exclusively offshore, will be made in this decade.

References


